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# Simulation-Based Assessment of Automated Command, Control, and Communication Capabilities for Armor Crews and Platoons: The Intervehicular Information System

Robert S. Du Bois and Paul G. Smith
Universal Energy Systems, Inc.

January 1991



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The Army is assessing the benefits of including an automated $C^3$ display, the Intervehicular Information System (IVIS), in the upgraded Block II M1 Abrams tank. This simulation-based research compared the performance of 24 tank crews and 6 tank platoons using a prototype IVIS with the performance of 24 tank crews and 6 tank platoons using conventional $C^3$ and navigational tools, including a radio, paper map, protractor, and compass. The research supported including IVIS in future tank upgrades. Armor crews and platoons equipped with IVIS significantly outperformed the crews and platoons using conventional techniques on every composite measure evaluated. IVIS-equipped crews and platoons executed a $C^3$ exercise and offensive and defensive combat missions faster, reported their own location and battlefield events better, and successfully executed more fragmentary orders than crews and platoons equipped with conventional tools. The findings also suggest critical Armor performance, training, and standard operating procedure implications and identify and reflect on IVIS system design and functional requirements.

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## FOREWORD

To assist the United States Army in achieving maximum effectiveness on the future AirLand battlefield, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research on critical soldier performance and training issues. The Future Battlefield Conditions Team of the ARI Field Unit at Fort Knox uses simulation and field-based evaluations of soldier performance when using prototype Armor weapon systems to enhance soldier performance. ARI's research on future battlefield conditions supports the memorandum of understanding between ARI and the U.S. Armor Center and School signed 12 April 1989.

This technical report provides data on the performance of soldiers using a new automated command, control, and communication ($C^3$) display, the Intervehicular Information System (IVIS), in the upgraded Block II M1 Abrams tank. The results of this evaluation provide Armor commanders, combat developers, and combat modelers data concerning the potential Armor combat performance contributions, training implications, and system design and functional requirements of an IVIS display.

The criterion-oriented $C^3$ performance scoring strategies used in this research were reviewed and refined in August 1989 by a subject matter expert panel from the Command, Control, Communication, Computers, and Intelligence ($C^4$) Cell and Operations Research Systems Analysis (ORSA) Branch of the Fort Knox Directorate of Combat Developments (DCD). Results of this effort were briefed to the Chief of the DCD ORSA Branch on 4 October 1989.

EDGAR M. JOHNSON
Technical Director

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SIMULATION-BASED ASSESSMENT OF AUTOMATED COMMAND, CONTROL, AND COMMUNICATION CAPABILITIES FOR ARMOR CREWS AND PLATOONS: THE INTERVEHICULAR INFORMATION SYSTEM


## EXECUTIVE SUMMARY

Requirement:

To improve Armor small unit command, control, and communication ($C^3$) performance, the United States Army is evaluating the utility of including an automated $C^3$ display, the Intervehicular Information System (IVIS), in the upgraded Block II M1 Abrams tank. This research evaluated IVIS, as represented in the Simulation Networking-Developmental (SIMNET-D) test bed, by comparing the performance of tank crews and platoons using a prototype IVIS with the performance of tank crews and platoons using conventional $C^3$ tools and procedures.

Procedure:

A between-groups multivariate design was used. Twelve tank platoons, 48 tank crews, were randomly assigned to either an IVIS or control (NO IVIS) group. Each platoon completed a 1-1/2-day training program and 2-1/2 days of testing. The soldiers completed a small unit $C^3$ exercise and platoon combat missions on the SIMNET-D battlefield.

Findings:

Tank crews and platoons equipped with IVIS performed significantly better than control crews and platoons on each of 11 composite performance measures evaluated. IVIS-equipped units completed the $C^3$ exercise and missions faster, reported their location and battlefield events better, and successfully executed more fragmentary order, battle position occupation, and obstacle bypass tasks than conventional units.

Utilization of Findings:

The results of this research support including an IVIS display in the upgraded M1 Abrams tank. The soldier performance data bases generated provide Armor commanders, combat modelers, and combat developers with a basis for deriving estimates of IVIS's potential contributions across a wide range of combat, combat support, and

combat service support measures. These results also describe soldier reactions to the IVIS interface and identify IVIS research, training, and design issues.

SIMULATION-BASED ASSESSMENT OF AUTOMATED COMMAND, CONTROL, AND COMMUNICATION CAPABILITIES FOR ARMOR CREWS AND PLATOONS: THE INTERVEHICULAR INFORMATION SYSTEM

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# SIMULATION-BASED ASSESSMENT OF AUTOMATED COMMAND, CONTROL, AND COMMUNICATION CAPABILITIES FOR ARMOR CREWS AND PLATOONS: THE INTERVEHICULAR INFORMATION SYSTEM

The U.S. Army Armor force's conventional command, control, and communication ($C^3$) procedures, based primarily on FM radio communications, arm and hand signals, and paper maps with graphic mission overlays, are challenged by the requirements of the future battlefield. The mass kill capabilities of a numerically superior, technologically sophisticated, and nuclear-equipped enemy force demand effective Armor $C^3$ performance at all levels, but especially at the small unit level, battalion, and below. Armor commanders must complete difficult combat mission requirements that rapidly change under dispersed and autonomous conditions. They must maintain a synchronized, aggressive, deceptive, and mobile force to survive, fight, and win. To facilitate effective small unit $C^3$ performance, the U.S. Army Armor Center is currently assessing the benefits of including an automated $C^3$ display, the Intervehicular Information System (IVIS), in the upgraded Block II M1 Abrams tank.

IVIS is a computer-based distributed information management system proposed to improve lower echelon $C^3$ performance. $C^3$ includes "the process of monitoring the enemy and friendly situations through effective use of communications" (Directorate of Combat Developments (DCD), 1988a). $C^3$ is a complex and critical process that is the backbone of Army effectiveness in all AirLand Battle doctrine operations (U.S. Army Science Board, 1986). IVIS, as currently defined, will provide Armor vehicle commanders with automated and secure (digital burst) battlefield information reporting tools and mutual position navigation (POSNAV) functions. These tools and functions are supported by a terrain map on an analog spatial display. IVIS is designed to help commanders synchronize their battlefield assets by providing them with a common picture of the battlefield. IVIS capabilities could permit ready access to and communication of the most accurate and timely battlefield and navigation information possible (Blasche & Lickteig, 1984; Polk & Lee, 1987).

The Army's advanced experimental test bed, Simulation Network-Developmental (SIMNET-D), provides resources that directly support the simulation and evaluation of new Armor capabilities. As demonstrated in recent SIMNET-D based POSNAV, Forward Area Air Defense System (FAADS), and M1 Block II evaluations (i.e., Du Bois & Smith, 1989; Pate, Lewis, & Wolf, 1988; and Directorate of Combat Developments (DCD), 1988b), SIMNET-D allows researchers to create a task-loaded, target rich combat environment where new system concepts can be objectively evaluated <u>before</u> actual system hardware is fielded.

The current research compared the performance of tank crews and platoons using a prototype IVIS with the performance of crews and platoons using conventional $C^3$ and navigation tools. This research focused on soldier performance using simulated IVIS capabilities rather than concentrating directly upon the engineering and hardware requirements for actual system development.

This research was conducted early in the IVIS materiel acquisition process and evaluated the IVIS concept as represented in reconfigured SIMNET-D M1 simulators. This evaluation included (a) an assessment of the tank crew and platoon performance effects of IVIS; (b) an examination of the unique training requirements of IVIS; and (c) an evaluation of soldier use of, and reactions to, the IVIS soldier-machine-interface (SMI). The research findings suggest critical Armor performance, training, and standard operating procedure (SOP) implications as well as identify and reflect upon IVIS system design and functional requirements.

## Review of the Literature

Previous research has examined IVIS and other Armor small unit $C^3$ system concepts from many perspectives. Army researchers have evaluated not only the soldier performance effects of a new Armor $C^3$ system, but also the data transmission, unit sustainment training, information presentation, and user interface design requirements. Some of this research has been conducted in SIMNET-D. In the sections that follow, literature pertaining to both SIMNET-D and the IVIS $C^3$ system concept are reviewed.

## The SIMNET-D Experimental Test Bed

### General Description

The Army's SIMNET-D test bed interactively links a variety of combined arms simulators, including M1 tanks, Bradley Fighting Vehicles, FAADS, and A-10 and Apache aircraft, along with microcomputers representing tactical, administrative, and logistical combat service support elements (Miller & Chung, 1987). SIMNET-D can support both local-area and long-haul network interaction of simulators for Armor battalion and below research. SIMNET-D's combat simulators and relevant research capabilities, including their advantages and disadvantages for $C^3$ research, have been described in previous U.S. Army Research Institute (ARI) technical reports (Du Bois, 1989; Du Bois & Smith, 1989). A brief description of the SIMNET-D test bed resources follows.

## SIMNET-D Combat Vehicle Simulators

SIMNET-D vehicle simulators model real system behavior to the minimum degree necessary for soldiers to perceive them as realistic and acceptable (Chung, Dickens, O'Toole, & Chiang, 1988; U.S. Army Armor School (USAARMS), 1987). Individual simulators are supported by a terrain and operations database and audio and visual systems for modeling battlefield conditions, equipment status, and weapon system performance. All simulator battlefield appearance, status, activities, and weapon system effects are linked and updated across an Ethernet.

Consistent with a selective fidelity design, however, SIMNET-D vehicles do not include all weapon system components. For example, the SIMNET-D M1 lacks the real M1's machine guns, auxiliary sight, and open-hatch. Likewise, the simulators' visual systems only present a daylight environment. Efforts are in progress to improve the fidelity of SIMNET-D simulators. Recently, a thermal imaging capability was added to the SIMNET-D M1 modules to support an evaluation of the Commander's Independent Thermal Viewer (CITV), another system proposed for the Block II M1. Nevertheless, researchers must evaluate the simulated modules' and combat development system's features to ensure that their level of fidelity is appropriate for the research issues being evaluated.

## SIMNET-D Research Capabilities

Several research capabilities directly support the SIMNET-D test bed. These capabilities include: (a) reconfigurable simulators; (b) Semi-Automated Forces (SAF) workstations; (c) Plan View Displays (PVDs); (d) shadow view monitors; (e) the Management, Command, and Control System (MCC); and (f) the Data Collection and Analysis System (DCA). These capabilities are described in Table 1.

## SIMNET-D Disadvantages and Advantages

Disadvantages. The SIMNET-D environment has at least three limitations when compared with field operations settings; these are (a) the closed-hatch nature of vehicle simulators; (b) the minimal visual cues presented; and (c) the lack of realistic, terrain bound and sensitive, communication systems. Also, like their field counterparts, SIMNET-D equipment (particularly the simulators, SAF, and simulated combat development) does break down.

The potential for these limitations to affect research findings must be carefully analyzed. For example, researchers have demonstrated significant performance degradations in closed-

Table 1

SIMNET-D Research Capabilities Description

| Capabilities | Description |
|---|---|
| Reconfigurable Simulators | The SIMNET-D simulator hardware and software are reconfigurable. Hence, the Army can simulate, evaluate, and redesign a new capability, like a new combat vehicle or subsystem, before building the actual system. |
| Semi-Automated Forces (SAF) | The SAF is a multi-vehicle simulation program for creating and controlling automated, unmanned, opposing and friendly forces' aircraft and vehicles. |
| Plan View Display (PVD) | The PVD monitor provides a "bird's eye view," in real time or playback, of a SIMNET-D exercise. The PVD depicts a terrain map and provides map manipulation and event flagging functions. |
| Shadow View Monitors | Shadow view monitors allow experimenters to observe, in real time or playback, SIMNET-D scenario events from selected vehicle vision blocks and sights. |
| Management, Command, and Control System (MCC) | The MCC provides service support stations and functions for battle management, simulator and target placement, fire support, close air support, and combat service support. |
| Data Collection and Analysis System (DCA) | The DCA supports automated soldier performance measurement. The DCA includes the Data Logger (DL), RS/Probe[1] (previously DataProbe), and RS/1. The DL records all Ethernet data packet traffic. RS/Probe and RS/1 are data management and analysis software packages. |

[1]"RS/Probe", "DataProbe", and "RS/1" are registered trademarks of BBN Software Products Corporation.

hatch field navigation and target acquisition (Barron, Lutz, Degelo, Havens, Talley, Smith, & Walters, 1976).

SIMNET-D does offer compensatory features for reducing the effects of some of these limitations, including an Azimuth Indicator, Turret Reference System, and special paper maps. Moreover, one of these limitations may inadvertently serve as a positive caveat for some research. Most AirLand battlefield operations will occur in closed-hatch NBC, artillery, and small arms fire environments. Hence, SIMNET-D research results may generalize quite well to the future battlefield. SIMNET-D combat scenarios can also be carefully designed to control limitation effects on exercise performance. Nevertheless, until research is conducted to assess the validity of SIMNET-D research, evaluators must be careful in assuming that their effects generalize to field and, ultimately, to actual combat performance.

Advantages. SIMNET-D offers many unique advantages over other simulations or field exercises. For example, the fidelity of $C^3$ assessments in SIMNET-D may be greater with respect to (a) the realism of task-loaded environments; (b) the realism of combat stress levels and communications; and (c) the capability for automated, objective performance measurement (Du Bois, 1989). Therefore, in SIMNET-D, soldiers can execute collective $C^3$ tasks not supported by other simulations. SIMNET-D also supports performance assessment at many unit levels, including battalion and below, with multiple weapon systems and logistical resources. SIMNET-D allows researchers to collect diverse data, including mission, soldier, and human factors measures that may not be objectively or safely evaluated in the field.

Furthermore, SIMNET-D can save time, costs, and resources required for field $C^3$ assessments. Exercise control capabilities, including those provided by the PVD, SAF, and MCC, ease the complexity of coordinating multi-combat vehicle exercises. Moreover, the rapid reconfigurability of the SIMNET-D combat vehicle simulators and the efficiency of the DCA system can result in significant cost savings (Schwab, 1987).

## The Intervehicular Information System

### General Concept Description

IVIS is a computer-based and distributed $C^3$ device concept. Presumably, IVIS will provide commanders with rapid access to critical battlefield information. This rapid information access capability could not only speed up the decision cycle of commanders but also ensure that everyone has the same view of the battlefield. In essence, IVIS is expected to substantially improve the Army's current FM radio communication system, which

is "hard-pressed...[and] hampered..by sluggish information processing and...handling" (Polk & Lee, 1987, p. 26). For more detailed descriptions of the problems in the Army's current FM voice communications, see Phelps and Kupets (1984) and Coleman, Stewart, and Wotten (1986).

The potential need for an automated $C^3$ system for Armor small units has been recognized for several years (e.g., Blasche & Lickteig, 1984). Higher echelon Armor units are currently using or in the process of implementing advanced computerized $C^3$ systems, such as the Maneuver Control System (MCS) and the Army Command and Control System (ACCS). The needs are increased by evolving computerized communication and information management capabilities, intensifying future battlefield expectations, and increasing dependence of higher units on rapid, accurate information. As a result, the Army has proposed and evaluated several new Armor small unit $C^3$ system concepts. IVIS is one small unit $C^3$ system concept. Other concepts include the Vehicle Integrated Intelligence System [$V(INT)^2$] and the Battlefield Management System (BMS). The diversity of these concepts reflects the Army's many perspectives on the particular functions, capabilities, and technologies that could eventually enhance an automated Armor small unit $C^3$ system's contributions to combat performance effectiveness.

Research Findings

Although the U.S. Army has not completely decided on the specific functions IVIS will perform or which combat vehicles will carry IVIS, Army researchers have considered possible IVIS user interface design, information presentation, training, and data transmission requirements. The outcomes of these efforts, described below, have been incorporated--where possible--into the current simulation-based experiment.

Blasche and Lickteig (1984) examined the characteristics of an automated command and control network, $V(INT)^2$, to determine the volume, format, and level of battlefield information required by commanders at different levels of combat support. Blasche and Lickteig also identified and illustrated the functional capabilities needed for the effective acquisition, transmission, and interpretation of battlefield information. Their report has become a prime resource in determining the potential benefits of various IVIS functional capabilities to Armor commanders.

Lickteig (1986) extended the work of Blasche and Lickteig (1984) by examining potential $C^3$ system user interface requirements. A prototype IVIS was developed and evaluated from a user-interface perspective with a cross-section of small-unit Armor leaders as user-evaluators. The prototype's interface was designed with reference to published human factors guidelines for

the design and development of user friendly interactive computer systems (e.g., Hendricks, Kilduff, Brooks, Manshak, & Doyle, 1983; Muckler, 1984; Sidorsky, Parrish, Gates, & Mungen, 1984). This prototype IVIS display is reproduced in Figure 1.

Overall, the user-evaluators specified numerous modifications necessary to enhance the IVIS display, including the need for a variety of map terrain features and functions that permit users to tailor their displays to current battlefield conditions. Users also suggested a number of menu modifications and identified preferences regarding the overall configuration, size, and operating characteristics of the IVIS interface.

Jobe (1986) performed two survey-based analyses to determine the information requirements of IVIS. In the first survey evaluation, 30 Armor officers and non-commissioned officers (NCOs) rated 34 potential IVIS information items on the basis of their necessity for mission success. These ratings were compared to the ratings of four Armor subject matter experts (SMEs).

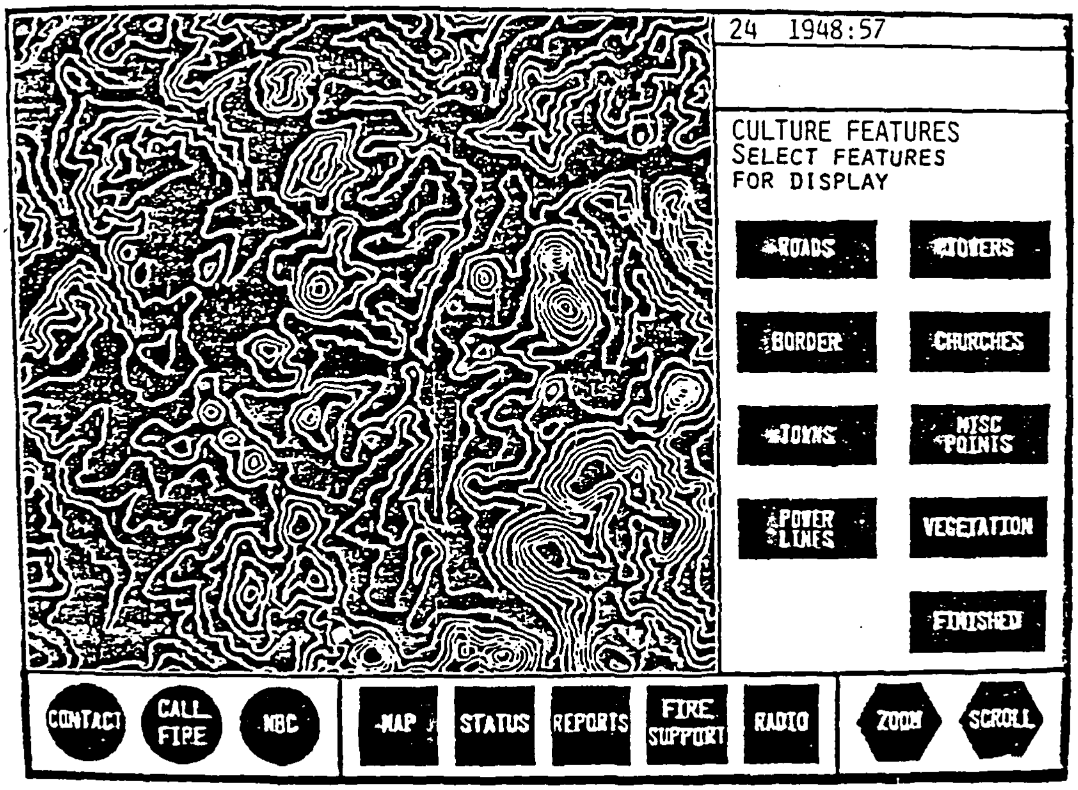


Figure 1. The prototype IVIS interface design evaluated by Lickteig (1986)

Results indicated significant agreement among Armor officer/NCO and SME raters about the information requirements for three platoon duty positions: platoon leaders, platoon sergeants, and tank commanders. The ten most essential information items across the two groups of raters are listed below:

1. Critical situation alert
2. Concept of operations
3. Vehicle identification (friend or foe)
4. Vehicle heading
5. Call for fire
6. Command mission
7. Reports (formats)
8. Maintenance status
9. Ammo and fuel remaining
10. Enemy weapon systems

Numerous information presentation requirements were also suggested by the raters, including a preference to have most information elements displayed in either a graphic (map) display or alphanumeric format as opposed to bar and pie charts.

In the second survey evaluation, six Armor officers and ten Armor NCOs, all of whom participated in the earlier evaluation, examined an IVIS prototype. This prototype display included information designed to assist Armor commanders in (a) navigation, (b) the identification of friendly and enemy positions, (c) the communication of fuel and ammo status, and (d) the recognition of alert situations and equipment failures. Each commander first completed numerous tasks using the prototype IVIS display, such as assigning sectors of observation and creating a map overlay, to become familiar with the $C^3$ system. Commanders then rated the necessity of each of the prototype IVIS display functions for mission accomplishment.

Overall, no differences in mission necessity ratings were discovered across IVIS functions. All display functions were rated as equally essential for mission accomplishment. However, commanders indicated a preference for two primary clusters of information for presentation on IVIS--one logistical (e.g., ammo status) and one tactical (e.g., enemy and friendly positions). Furthermore, when asked to indicate their preferred method for interacting with IVIS, most of the commanders suggested either a touch screen or a voice interaction capability.

Lickteig (1987) provided a preliminary identification of the training requirements for IVIS. The primary objective of Lickteig's analyses was to subjectively identify the range and nature of changes in Armor commander task performance which were anticipated to result from the introduction of automated $C^3$ systems to Armor units, battalion and below. Three generations of IVIS were projected and evaluated, beginning with IVIS in the

near term, and progressing to a midterm upgrade, BMS, and a far term system enhanced by artificial intelligence (AI), BMS/AI.

Overall, Lickteig documents the pervasive impact automated $C^3$ systems may have on the current tasks, subtasks, and standards associated with platoon performance. A primary conclusion is that these automated $C^3$ systems will substantially reduce the current $C^3$ task requirements associated with small unit leadership. Other conclusions include the following:

> 1. For nonresident training...the computer-based nature of these automated systems provides an excellent medium for embedded training programs.
>
> 2. ...for residential training, computer-based instructional (CBI) programs [should] be developed in support of these automated $C^3$ systems.
>
> 3. ...the development of these automated training systems should be pursued as quickly as possible.... In particular, the issues of informational overload and personnel assignment and selection can only be accurately assessed when operative systems are placed in the hands of potential users and trainers. (Lickteig, 1987, p. 13)

An important product of Lickteig's analyses was a series of tables which indicate the level of commonality between the training requirements of current platoon leader/platoon tasks, subtasks, and standards, and the requirements expected for these same tasks, subtasks, and standards with each of the three anticipated generations of IVIS. These tables also indicate the expected difficulty associated with training tank platoon tasks, subtasks, and standards for each IVIS generation, as well as the hardware configuration (stand alone IVIS versus networked IVIS systems) required for training each task, subtask, and standard.

A recent report evaluated the data requirements of IVIS to support company tactical communications in two "hasty attack" missions at the Army's National Training Center (Polk & Lee, 1987). The authors examined "peak stress points" across missions where events became unplanned, spontaneous, and stressful. These radio traffic data were used to determine the memory size and data bit rate requirements of IVIS, two fundamental architectural issues. The major conclusions reached in this NTC research included:

> 1. The information requirements of IVIS as exhibited by the activity on a voiced net do not pose an insurmountable challenge with regard to current microprocessor capabilities.

2. The struggle to communicate digitally through IVIS will be driven by the proposed graphical requirements and not the voiced requirements.

3. The hardware required to support the IVIS information requirements is not unreasonable. The application of digital equipment to solve battlefield reporting and information processing requirements is a realistic, obtainable goal, and should be pursued. (Polk & Lee, 1987, p. 4-5)

Schwab (1988) evaluated the integration of an IVIS prototype into an M1 tank and its tactical usefulness to tank commanders. Following the completion of field-based training and testing using IVIS, three tank commanders rated the IVIS prototype's design and potential combat effectiveness. Although the IVIS prototype's hardware and software fell short of expected performance (IVIS was only operational for three of the eleven evaluating days scheduled), the commanders evaluated were enthusiastic about the tactical potential of IVIS. Some of the commanders' suggestions included the need for a color display for distinguishing map features and a revised, smaller tank icon that depicts the orientation of the tank's hull and turret.

DCD (1988b) recently conducted a SIMNET-D based evaluation of the M1 Block II tank. The objectives of this evaluation were: (a) to gain insights into Block II component function, control, and display requirements; (b) to identify and evaluate alternative measures of effectiveness for describing Block II component synergy; and (c) to evaluate the effectiveness of SIMNET-D as a research and development tool. A single Armor platoon completed both offensive and defensive combat missions with and without the prototype Block II components. The Block II M1 tanks were represented by reconfigured SIMNET-D tanks, which included a prototype IVIS with its POSNAV subsystem, and CITV.

Overall, DCD's Block II evaluation demonstrated support for the Block II components, particularly for $C^3$ performance. When equipped with IVIS (with POSNAV) and CITV, the platoon completed the missions faster, with better formations, reduced radio transmissions, and more accurate reports. Moreover, some improvements were detected in Block II platoon target servicing, mobility, survivability, and cohesion. DCD recognized, however, the need for more research to evaluate Block II component system concepts, particularly given the limited scope, statistical power, and experimental design of their effort.

Recently, ARI completed two SIMNET-D experiments relevant to the current IVIS test, including an evaluation of the Block II POSNAV system (Du Bois & Smith, 1989) and the development and evaluation of a $C^3$ assessment methodology (Du Bois, 1989).

Du Bois and Smith (1989) evaluated a prototype POSNAV system, a major IVIS subsystem, by comparing the performance of crews and platoons using either a POSNAV grid or terrain map display with the performance of crews and platoons using conventional navigation tools, such as a map and compass. Sixty tank crews, 15 tank platoons, participated in the ARI POSNAV experiment. Twenty crews, five platoons, were assigned to one of the three treatment conditions: the POSNAV Grid Map, POSNAV terrain map, and baseline (NO POSNAV) groups. The entire IVIS interface was represented for this POSNAV research, but only the POSNAV-specific functions were operational.

Findings strongly supported including a POSNAV display in future tank upgrades. Armor crews and platoons equipped with POSNAV performed significantly better than crews and platoons using conventional navigational techniques in completing a series of crew tactical road marches and platoon combat missions. POSNAV-equipped crews and platoons completed marches and missions quicker, used less fuel, and reported checkpoints, enemy vehicle and shelling locations, and own-tank locations faster and more accurately.

POSNAV issues addressed in this report included: soldier performance and training implications, user acceptance, functional requirements, and potential combat, combat support, and combat service support effects. The ARI POSNAV test provides valuable data for evaluating the incremental effects of IVIS $C^3$ capabilities on tank crew and platoon performance and training.

Du Bois (1989), in research conducted simultaneously with the current effort, documents the need for and initial development of simulation-based Armor small unit commander $C^3$ performance assessment methods. Nine $C^3$ tasks were selected for measurement in SIMNET-D. Multiple objective performance measures were identified and supported the development of criterion-oriented composite measures for each task. Small unit $C^3$ task requirements were embedded in a 30-kilometer tactical exercise. Twenty-four tank crew and platoon commanders, with their crews, completed the prototype small unit $C^3$ exercise.

Overall, the performance data obtained demonstrated the potential of simulation-based $C^3$ assessment. Six of the $C^3$ composite measures possessed split-half and Cronbach's alpha reliability coefficients above .50. The small unit $C^3$ exercise developed served as the instrument used to assess IVIS tank crew performance effects in the current research.

The SIMNET-D IVIS Prototype

The IVIS prototype evaluated in the current research contained a nine-inch diagonal display screen and used a touch-sensitive screen input device. Specific user interface design and functional requirements of the IVIS prototype were developed by ARI, based on (a) accepted human factors guidelines; (b) the users' current estimate of their interface requirements for automated $C^3$ systems (e.g., DCD, 1988b; Du Bois & Smith, 1989; Jobe, 1986; Lickteig, 1986), and (c) current IVIS design descriptions and recommendations (DCD, 1988b; Lickteig, 1988). The IVIS prototype's hardware and software were integrated into SIMNET-D M1 simulators by the Defense Advanced Research Projects Agency's support contractor for SIMNET-D, BBN.

The prototype IVIS display, shown in Figure 2, was partitioned into six distinct sections:

1. An analog spatial map display with vehicle icons
2. An own-location and heading window
3. A series of soft-switch function keys, supporting access to reporting, map manipulation, and navigation capabilities
4. A variable menu area with **RECEIVE** function key
5. An alert window
6. A date/time window

Map Display Area. Beginning in the upper left hand corner, a four inch by four inch map display provided an overhead view of the battlefield area surrounding one's own tank. This map display was based on digital terrain data from the SIMNET-D terrain data base. A primary feature of IVIS is its ability to link critical navigation and battlefield information such as friendly unit locations and reported enemy locations to the map display. As part of the POSNAV subsystem, one's own tank and other friendly unit locations are represented on the IVIS map by tank icons and updated every 10 meters. Enemy positions based on the grid locations indicated in battlefield reports were represented on the map display by special symbols, including red stars for enemy contact reports and vehicle symbols for spot reports.

Own-Location and Heading Window. The own-vehicle grid location and heading window, situated in the lower right corner of the IVIS map display area, depicted the current own-tank location as an eight digit grid and the current own-tank compass heading in degrees. As the simulated tank moved, this information was automatically updated and displayed in the own location window, supplementing the graphic indication of the own-tank location and heading provided by the placement and orientation of one's own tank icon on the IVIS map.

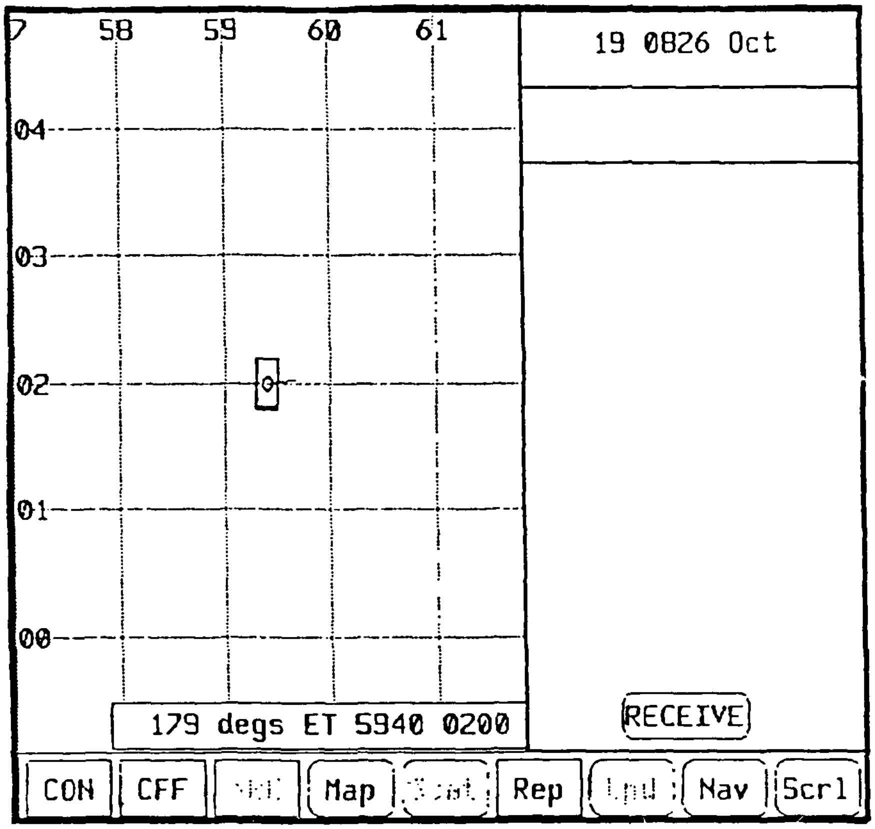


Figure 2. The prototype IVIS user interface.

<u>Function Keys</u>. The IVIS system menu function keys were included at the bottom of the IVIS display. These functions represented dedicated soft switches which commanders use to initiate various $C^3$ functions. IVIS is expected to include several functional capabilities, not all of which were operational in the present research's SIMNET-D based IVIS prototype.

As Figure 2 shows, only the contact (**CON**), call for fire (**CFF**), map (**MAP**), reports (**REP**), navigation (**NAV**), and scroll (**SCRL**) function keys were operational. The nuclear, biological, and chemical (**NBC**), status (**STAT**), and update (**UPD**) function keys are expected in the fielded IVIS system and were not evaluated in this research.

<u>Reporting Functions</u>. The prototype IVIS included several report and alert function keys which allowed commanders to access, prepare, and transmit six battlefield and logistics reports. These reports, and their supporting menu key(s), included: (a) contact reports (**CON** or **REP**); (b) call for fire

requests and adjustments (**CFF** or **REP**); (c) spot reports (**REP**); (d) shell reports (**REP**); (e) ammunition status reports (**REP**); and (f) situation reports or SITREPS (**REP**).

The **REP** key, a global report and alert function key, includes menus and submenus for enabling the preparation and transmission of each of the reports listed above. The **CON** and **CFF** function keys represent dedicated report keys to provide an additional, more rapid means for preparing and transmitting two especially critical reports: contact reports and calls for fire, respectively.

After having touched the appropriate report function key on the IVIS display screen, the commander would interact with menus and submenus to input selected report fields. These menus were presented, one-at-a-time, in the IVIS variable menu area to the right of the map display. For example, the **CON** key menu, shown in Figure 3, supported the preparation and transmission of contact reports which included both "what" (e.g., tank, PC) and "where" (e.g., grid location) data fields. To indicate the reported enemy's six-digit Universal Transverse Mercator (UTM) grid location, commanders could either lase to the target using their tank's laser range finder (LRF) or touch the map display area at the enemy's estimated grid location.

Once the report data is logged, the commander presses ENTER. Then, a "SEND IF READY" message and a report content summary appear in the menu area. In addition, a red star is depicted at the map location where enemy contact is indicated. Pressing SEND results in report transmission. For platoon leaders, transmitted reports were automatically distributed to the other tank commanders in the platoon and also to the company commander. For tank commanders, transmitted reports were automatically sent to the platoon leader and to other tank commanders in the platoon. Throughout IVIS report preparation, commanders are presented with EXIT or CANCEL menu options which allow them to immediately leave report preparation and transmission menus, respectively.

<u>Map Manipulation Functions</u>. The **MAP** function key gave commanders access to several IVIS map display manipulation functions. These functions include a "map features", "map zoom", "map scroll", "map line of sight (LOS)", "map symbols", "map labels", "map spots", and "map overlay" function. Commanders can access these capabilities from the **MAP** key main menu at any time during a mission. Once activated, the **MAP** key main menu appears in the IVIS variable menu area.

The "map features" function allowed the IVIS commander to add or subtract color-coded terrain features (i.e., roads, vegetation terrain contour lines, and UTM grid lines) on the map display.

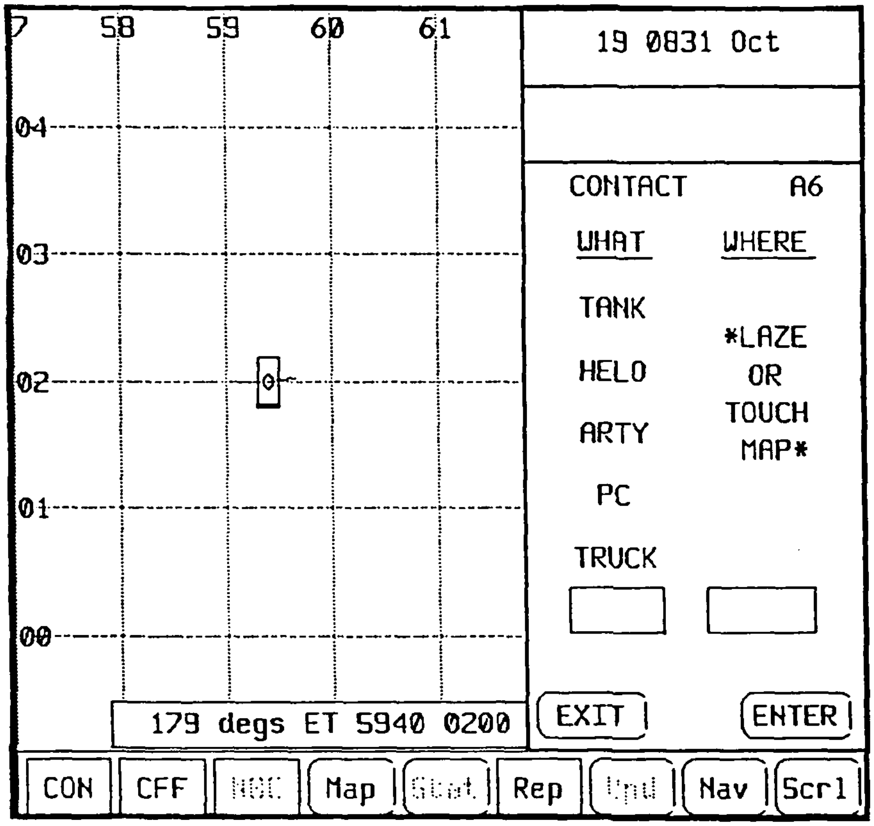


Figure 3. The prototype IVIS display screen **CON** menu.

The "map zoom" function permitted commanders to display the IVIS map area at three standard military map scales: 1:25,000, 1:50,000, or 1:125,000. These map scales allowed commanders to view map areas about three by three, five by five, and 11 by 11 kilometers, respectively.

The "map LOS" function allowed commanders to determine the intervisibility offered from selected battlefield grid locations, including their own-tank location. Intervisibility status was portrayed by a series of blue and red lines. A red line between two points indicated that a direct line of sight between the points exists. For this SIMNET-D based IVIS prototype, intervisibility information was based solely on SIMNET-D terrain contour intervals between points and not on vegetation or weather conditions. Commanders touched the map display area to indicate six-digit grid coordinates for intervisibility analyses.

The "map symbols" and "map labels" functions permitted commanders to place graphics onto their map display, including standard military symbols (e.g., checkpoints, target reference

points, and minefields) and labels (e.g., objective, axis, and phase line names). Both symbols and labels could be placed onto or deleted from the IVIS map one-at-at-a-time. Commanders could also send selected symbols and labels, one-at-a-time, to other friendly units. Once sent, these symbols or labels automatically appeared on the receiving units' IVIS map displays.

The "map spots" function provided commanders with a tool for removing, or subsequently recovering, a complete set of symbol and label graphics (all but dotted and solid lines) from the map display area. Hence, this function gave the commander a means to permanently, or temporarily, declutter the IVIS map display.

The "map overlay" function allowed commanders to place a mission graphic overlay onto the map display area. Only an overlay received by another IVIS commander could be shown or removed using this function. This function was designed to support the rapid reception and presentation of original mission or fragmentary order (FRAGO) graphics. This function also permitted the commanders to declutter the IVIS map display by temporarily removing the mission overlay, as needed. Only one mission overlay could be portrayed on the IVIS map at a time.

Another IVIS function key, **SCRL**, provided commanders with the capability to change the area portrayed on the map display. A commander could move the map by dragging the map with his finger (the "scroll drag" function) or by a series of discrete finger touches (the "scroll velocity" function. The commander could also return the map to the default setting where his own tank was presented in the center (the "scroll home" function). The "scroll lock" function allowed the commander to lock his IVIS map at a distinct location.

Navigation Functions. The **NAV** key gave the tank commander access to a route entry and management function, the "route designation" function. The "route designation" menu, accessed by pressing the **NAV** key, is presented in Figure 4. This function, specifically designed to support land navigation, is a principal component of the IVIS POSNAV subsystem.

The **NAV** "route designation" function provided a menu for entering and updating mission or road march route waypoint locations. Commanders touched the IVIS map display to indicate route waypoint grid coordinates. A maximum of seven route waypoints could be specified. The IVIS system portrayed the route on the map display area, monitored route progress, and updated the vehicle icon's location and orientation along the route designated.

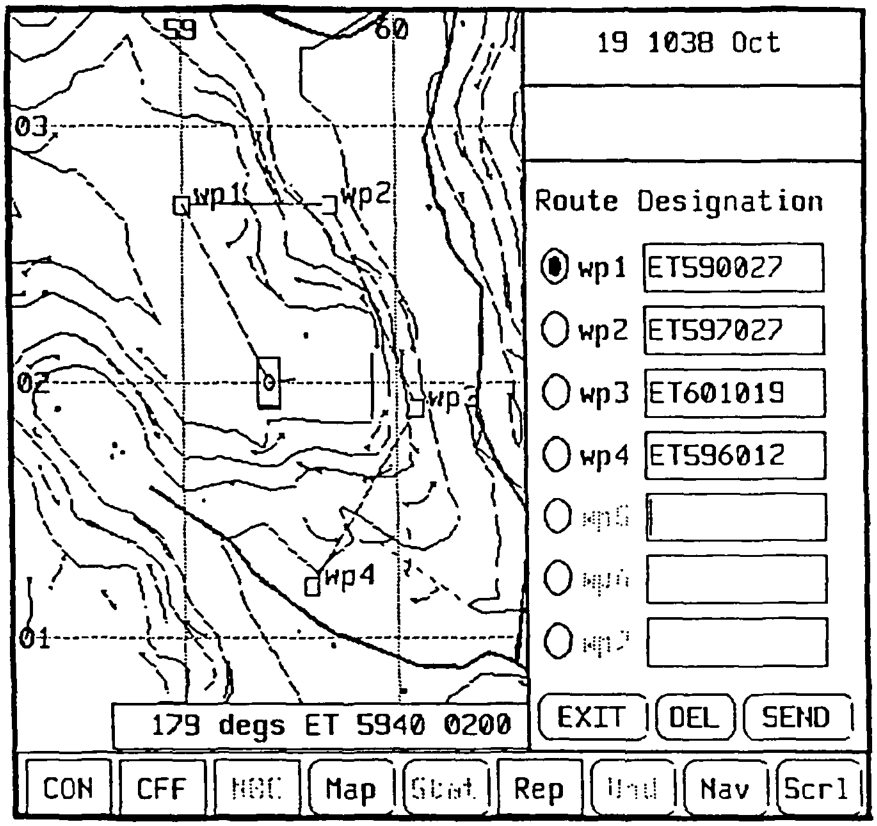


Figure 4. The prototype IVIS display **NAV** route designation menu.

The IVIS device also provided tank drivers with important route progress information. By touching the circle located next to each route waypoint on the **NAV** "route designation" menu, commanders could send waypoint identification information to a driver's "Steer-to" display. This "Steer-to" display is shown in Figure 5 and included:

1. The number of the waypoint currently displayed
2. Current own-vehicle distance from the next route waypoint
3. Current own-vehicle azimuth heading (in mils)
4. Current own-vehicle azimuth heading required to reach the next waypoint
5. A steer-to indicator which showed the direction the driver should steer the vehicle to reach the next waypoint

The commander could change the waypoint that was monitored by the driver's display at any time by selecting a new waypoint.

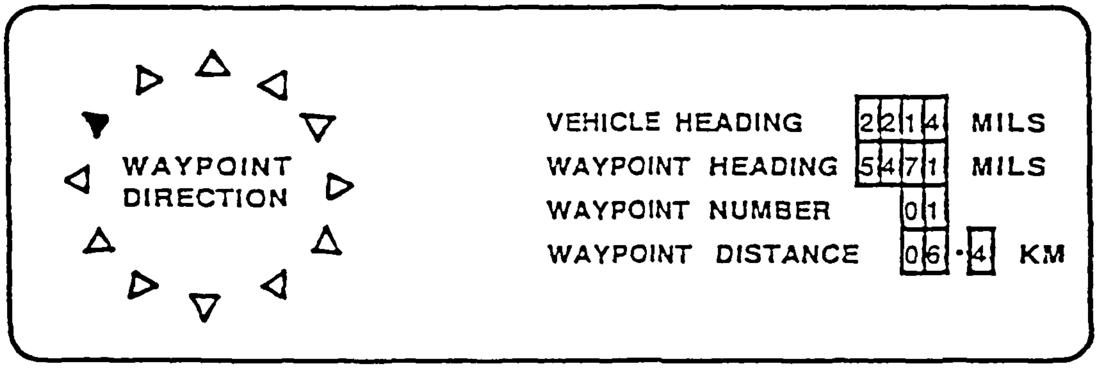


Figure 5. The prototype IVIS driver's display.

<u>Variable Menu Area and Receive Function</u>. As previously described, all IVIS function key menus appeared to the right of the map display in the variable menu area. When menus were not being shown, the variable menu area also houses a **RECEIVE** key for receiving other unit reports and graphic overlays. When a report entered the IVIS queue, a "MESSAGE WAITING" warning appeared in the alert window directly above the menu area. This visual cue was also accompanied by auditory tones presented through the tank's intercom. The commander pressed the **RECEIVE** key to select and read the report. If the IVIS menu area was occupied, the commander had to CANCEL, EXIT, or rapidly finish the task before the report could be called up from the IVIS queue.

As illustrated in Figure 6, the IVIS queue could hold several reports. When the **RECEIVE** key was touched, a library of the reports currently in the queue appeared in the menu area. For each report, this queue list showed its type, priority, and source. Reports were listed by priority (from highest (1) to lowest (3) priority). Mission graphics, always priority 1, were listed in the queue as FRAGOs. Once selected (with the "map overlay" function), the overlay appeared on the IVIS map display.

Commanders selected individual reports to be read by touching the report listed in the IVIS queue library. If the queue was more than one page long, the commander had to read some of the reports listed before other reports would appear in the queue to be called up. After reading the report, the commander could either discard the report by pressing EXIT or relay and/or save the report by pressing the action (ACT) option. Using the ACT option menu, commanders could relay IVIS reports to only higher, only lower, or to all commanders and/or save the report's data (i.e., an enemy location icon) onto their map display.

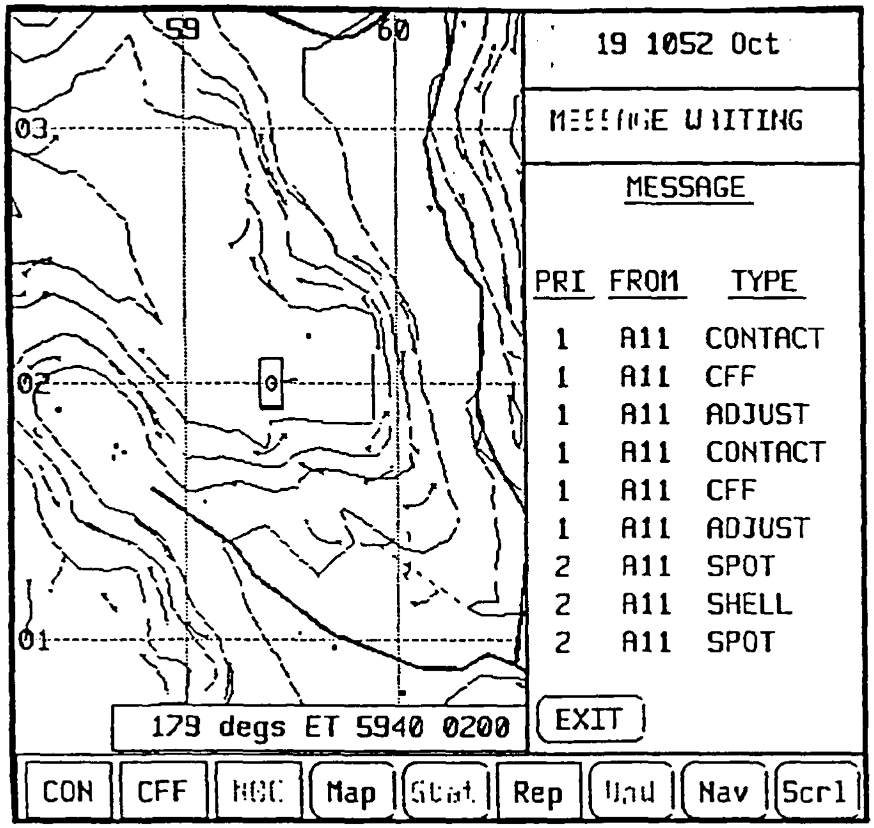


Figure 6. The prototype IVIS report queue.

Alert Window. Directly above the variable menu area, the alert window displayed a blinking warning, "MESSAGE WAITING", when reports arrived in the commander's IVIS queue. The frequency with which this message blinked indicated the report's priority. If multiple reports arrived before they could be called up, the visual and auditory warning cues presented corresponded to those of the highest priority report waiting to be read.

Date/Time Window. The date/time window, upper right corner of the IVIS display screen, continuously displayed the current day, time, and month.

Overall, the partitioning of the IVIS display into distinct sections with specified functions might suggest that the IVIS design, capabilities, and operating requirements are permanently assigned. This, however, is certainly not the case. SIMNET-D provides an excellent medium for exploring display-related issues and ultimately refining and enhancing this prototype display.

## Statement of the Research Problem

In summary, IVIS is expected to provide many benefits to the Army's Armor force. IVIS provides capabilities that could support near real-time acquisition, processing and distribution of combat information. Presumably, then, IVIS could result in a more rapid plans-orders cycle, more efficient and accurate reporting, and, ultimately, greater mission success. While soldiers and researchers have repeatedly indicated that IVIS appears to offer significant contributions to Armor combat effectiveness, no research has objectively demonstrated these benefits.

The primary purpose of this research is to investigate the performance effects on crew and platoon performance of a prototype IVIS system in the M1 tank using SIMNET-D. Tank crew and platoon performance with IVIS was compared to the performance of crews and platoons in a control group, NO IVIS, which used only conventional $C^3$ and navigational tools.

Selection of the IVIS display format was guided by the proponent's (USAARMC's) expectations regarding the system's potential operating characteristics. The current evaluation, using reconfigured SIMNET-D M1 modules and IVIS prototypes, provided Armor commanders, combat developers, and combat modelers with data concerning the potential Armor combat performance contributions, training implications, and functional requirements of an IVIS system. Unlike conventional field-based combat development evaluations, the current simulation-based research objectively evaluated the benefits of the IVIS developmental system <u>before</u> it is actually built and fielded--potentially avoiding costly product improvement and redesign requirements.

## Method

### <u>Conditions</u>

#### <u>Control Condition (NO IVIS)</u>

In the control or baseline condition, tank crews and platoons planned and executed the $C^3$ exercise and combat missions without the aid of the IVIS system. Hence, $C^3$ performance was accomplished using conventional $C^3$ tools, including radio network communications with other crew and platoon participants, the field of view from the tank's vision blocks and sights, the grid azimuth indicator, and the use of a paper map with a mission graphic overlay.

IVIS Display Condition (IVIS)

In addition to the $C^3$ tools available in the control condition, the tank crews and platoons in this condition were equipped with the IVIS system. The TC in this condition used a terrain map display with own-tank and other friendly tank position icons (mutual POSNAV). Location and heading information was indicated digitally in an "Own Location and Heading Window" and graphically on the IVIS map display, without error. The touch sensitive display also housed several operational function keys, including battlefield and logistics reporting functions (**CON**, **CFF**, and **REP**), map manipulation functions (**MAP**), a report reception function (**RECEIVE**), and a navigation function (**NAV**). The IVIS communication network was separate from the tank's radio network. Commanders were restricted, however, to using the IVIS system for sending reports.

A driver's display, showing movement progress information, was available as well. Figures 2 and 5 (presented earlier) illustrate the IVIS tank commander's and driver's display formats, respectively.

## Hypotheses

Based on previous IVIS and IVIS POSNAV subsystem research findings, directional hypotheses supporting significant IVIS crew and platoon performance contributions are tested in the current experiment. These research hypotheses included:

1. Crews equipped with the IVIS system, as represented in SIMNET-D, will perform significantly better across all objective $C^3$ exercise criterion measures than crews in the baseline or NO IVIS condition.

2. Platoons equipped with IVIS, as represented in SIMNET-D, will perform significantly better across all objective offensive and defensive combat mission criterion measures than platoons in the baseline or NO IVIS condition.

## Apparatus

This research was supported by numerous SIMNET-D test bed resources. These resources included four SIMNET-D M1 tank simulators, each reconfigured to include an IVIS commander's and driver's display. The nine-inch diagonal IVIS commander's display was represented on a high-resolution (1280 pixels by 1024 lines) 19V inch, 100 MHz Taxan color monitor with 0.31 dot pitch. The IVIS commander's display was mounted in the right front area of the M1 simulator's commander crew station. This is the

location currently anticipated for the fielded IVIS commander's display. The driver's display was mounted above and to the right of the driver's T-bar or steering column. Both IVIS displays were inactive during control group testing.

Additional SIMNET-D research capabilities previously described were also used. These capabilities included the SAF (one workstation), PVD (two displays), DCA (RS/Probe and RS/1), MCC (fire support, battle master, and SIMNET-D control console stations), and shadow view monitors (platoon leader vision blocks and sights). These resources were exploited to support test development and administration and data collection and analysis. A classroom in the SIMNET-D building was used for familiarization training of crews and platoons, as well as for all questionnaire administration and debriefing sessions. Training sessions incorporated the use of an overhead projector and video cassette player.

## Design

A between-groups design, illustrated in Figure 7, was used in the current experiment to evaluate tank crew and platoon performance across two levels of one independent variable: $C^3$ condition. In choosing a between-groups design, the trade-offs in terms of practicality, statistical power, and internal validity were carefully weighed before deciding whether a between- or within-groups design was most appropriate. While a within-groups design was initially favored because of its greater statistical power with small sample sizes, time restrictions for subject participation and SIMNET-D availability favored a between-groups design. Also, the very real possibility of differential "carry-over" effects from one test condition to another was a concern with the within-groups design. Ultimately, situational constraints were the major factors in the decision to use a between-groups design.

## Research Participants

### Soldier Participants

One-hundred and eighty soldiers stationed at Fort Knox, Kentucky, served as tank crew and platoon members for this research. Twelve soldiers participated each week across three weeks of pilot and twelve weeks of actual testing. Each unique group of 12 soldiers included one platoon leader, one platoon sergeant, two tank commanders, four drivers, and four gunners. These 12 soldiers were assigned to form four three-man tank crews, one 12-man tank platoon.

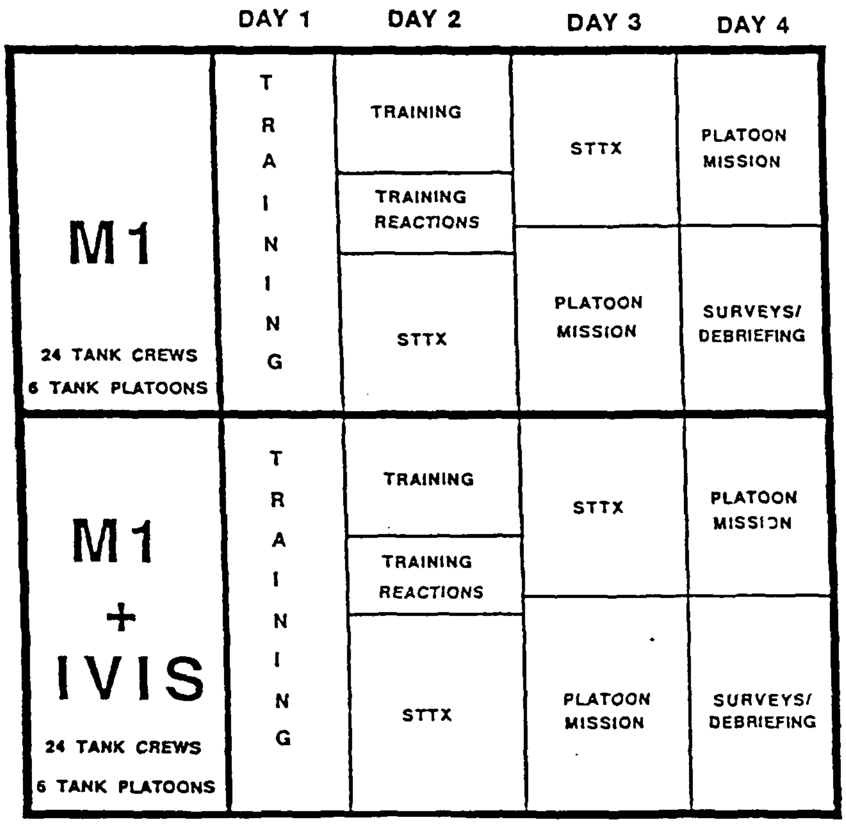


Figure 7. Between-groups design used in the current experiment.

A total of 15 tank platoons, 60 tank crews, participated in this research. Three tank platoons, 12 tank crews, supported pilot testing efforts. Forty-eight tank crews supported the actual crew evaluation (i.e., n=48 for crew evaluation). Twelve tank platoons supported the actual platoon evaluation (i.e., n=12 for platoon evaluation).

Ultimately, Army unit commanders decided on the particular soldiers who participated in this research. However, soldiers were required to be qualified for the tank position they served. Furthermore, each platoon was assigned to an experimental condition (IVIS or NO IVIS) using a sampling without replacement randomization procedure.

Tank crews were formed through a process of random assignment of the gunners and drivers to the platoon leader, platoon sergeant, or wingman tank. Tank crews and platoons participating in this research were not intact or formally established combat units. They were collections of individual crew members assigned to form four ad hoc crews or a platoon.

Loaders/Research Assistants

Four research assistants served as ammunition loaders and data collectors in this research. The primary reasons for using loader assistants were: (a) to minimize the number of soldiers required; (b) to allow an in-tank observer to collect various behavioral and process measures; and (c) to provide a training instructor for each crew. The loader position was especially suited for research assistant occupancy because the loader has relatively little influence over tank crew and platoon performance with regard to $C^3$ and land navigation tasks. In fact, the loader position is currently being evaluated by the Army for automation.

To take full advantage of the standardization possible with SIMNET-D, loader assistant behavior must be identical for all tank crews during the crew and platoon exercises. To achieve this uniformity, the four loader assistants received extensive training on SIMNET-D. Each loader assistant received about 100 hours of training. Forty hours of this training was formal and included: (a) an overview of the M1 tank, including a briefing on an actual M1A1 tank; (b) formal instruction on the $C^3$ tasks and procedures currently used by soldiers; (c) practice, with subject matter expert (SME) guidance, of the M1 tasks supported by SIMNET-D tank modules; (d) a description of the training program and test exercises used in this research; (e) use (and revision) of training scripts; (f) instructions for collecting behavioral observational data; and, (g) use (and revision) of data collection logs.

The loader assistants received an additional 60 hours of informal on-the-job training during the pilot stages of crew and platoon exercise development. There were repeated opportunities during training for loader assistants to operate the SIMNET-D vehicles, to use the training scripts, and to use the data collection logs.

## Instruments

Twelve instruments were used in this experiment. These instruments included a crew $C^3$ exercise, offensive and defensive platoon combat missions, an IVIS performance test, and several written knowledge tests and questionnaires. While many of these instruments were developed specifically to support this research, others were modified from previous research. Each of these instruments are described in Table 2.

Table 2

Summary of Instruments Used in the Current Experiment

| Instrument | Description | Objective |
|---|---|---|
| Armor Small Unit Command, Control, and Communication Exercise | Single tank tactical exercise requiring tank crew and platoon commanders, with their crews, to execute nine $C^3$ tasks. Completed by all crews. | Assess $C^3$ performance differences between crews in IVIS and control conditions. |
| Offensive Platoon Combat Mission | Movement to Contact/ Hasty Attack mission with change of mission. Completed by all platoons. | Assess $C^3$ performance differences between platoons in IVIS and control groups. |
| Defensive Platoon Combat Mission | Hasty Defense mission with change of mission. Completed by all platoons. | Assess $C^3$ performance differences between platoons in IVIS and control groups. |
| Biographical Questionnaire | Questionnaire for collecting Armor experience and aptitude data. Completed by all soldiers. | Describe the sample and assess, <u>post hoc</u>, test group equivalence. |
| Land Navigation Skills Test | Written test for assessing map reading and land navigation skills. Completed by all soldiers. | Evaluate, <u>post hoc</u>, test group equivalence. |
| SIMNET-D Knowledge Test | Written test for assessing SIMNET-D knowledge. Completed by all commanders. | Evaluate SIMNET-D training and assess, <u>post hoc</u>, test group equivalence. |

Table 2 (Continued)

Summary of Instruments Used in the Current Experiment

| Instrument | Description | Objective |
| --- | --- | --- |
| IVIS Knowledge Test | Written test for assessing IVIS knowledge. Completed by commanders in the IVIS group. | Evaluate IVIS training requirements. |
| IVIS Performance Test | Performance test for assessing IVIS hands-on proficiency. Completed by commanders in the IVIS group. | Evaluate IVIS training requirements. |
| IVIS Training Reactions Questionnaire | Questionnaire for assessing reactions to the IVIS training program. Completed by commanders in the IVIS group. | Evaluate IVIS training requirements. |
| IVIS Interface Questionnaire | Questionnaire for assessing soldier reactions to the IVIS user interface. Completed by commanders in the IVIS group. | Evaluate the IVIS interface. |
| Task Difficulty Questionnaire | Questionnaire for rating the difficulty of performing $C^3$ tasks. Completed by all commanders. | Assess workload differences between the commanders in the IVIS and control groups. |
| SIMNET-D Questionnaire | Questionnaire for assessing soldier reactions to SIMNET-D. Completed by all commanders. | Evaluate the usefulness of SIMNET-D for evaluating IVIS. |

## Armor Small Unit Commander $C^3$ Exercise

The Armor small unit commander $C^3$ exercise, developed by Du Bois (1989), is a prototype tank crew and platoon commander exercise. This exercise, depicted in Figure 8, is designed specifically to require and assess $C^3$ task performance.

The $C^3$ exercise approach borrows heavily from the single tank tactical exercises (STTXs) used in Army Training and Evaluation Program (ARTEP) and Platoon Level Battle Simulation (PLBS) exercises. Tank crew and platoon commanders, with their crews, were given an operations order (OPORD) requiring them to negotiate a primarily road-bound route. Along this route, each commander was presented with selected visual and auditory stimuli, such as enemy units, incoming artillery, or higher commander orders and communications, requiring the performance of one of nine critical $C^3$ tasks.

The nine $C^3$ tasks included in the small unit $C^3$ exercise, listed in Table 3 below, were selected by Armor subject matter experts (SMEs). These tasks were deemed, by SME consensus, as: (a) capable of realistic assessment in SIMNET-D; (b) critical to effective small unit combat performance; and (c) capable of standardized, rapid, objective measurement without requiring unacceptable support requirements (e.g, administrators, exercise participants). For additional information regarding the development of the small unit $C^3$ exercise, readers are urged to review Du Bois (1989).

Table 3

Task Requirements Included in the Armor Small Unit $C^3$ Exercise

| $C^3$ Task | Number of Times Task Required |
|---|---|
| 1. React to a change of mission. | 2 |
| 2. Bypass obstacles. | 2 |
| 3. Issue calls for fire. | 3 |
| 4. Report own location. | 4 |
| 5. Report control measures. | 7 |
| 6. Report enemy contact (CONTACT reports). | 6 |
| 7. Report battlefield activity (SPOT reports). | 6 |
| 8. Report indirect fire activity (SHELL reports). | 8 |
| 9. Select and occupy a battle position. | 1 |

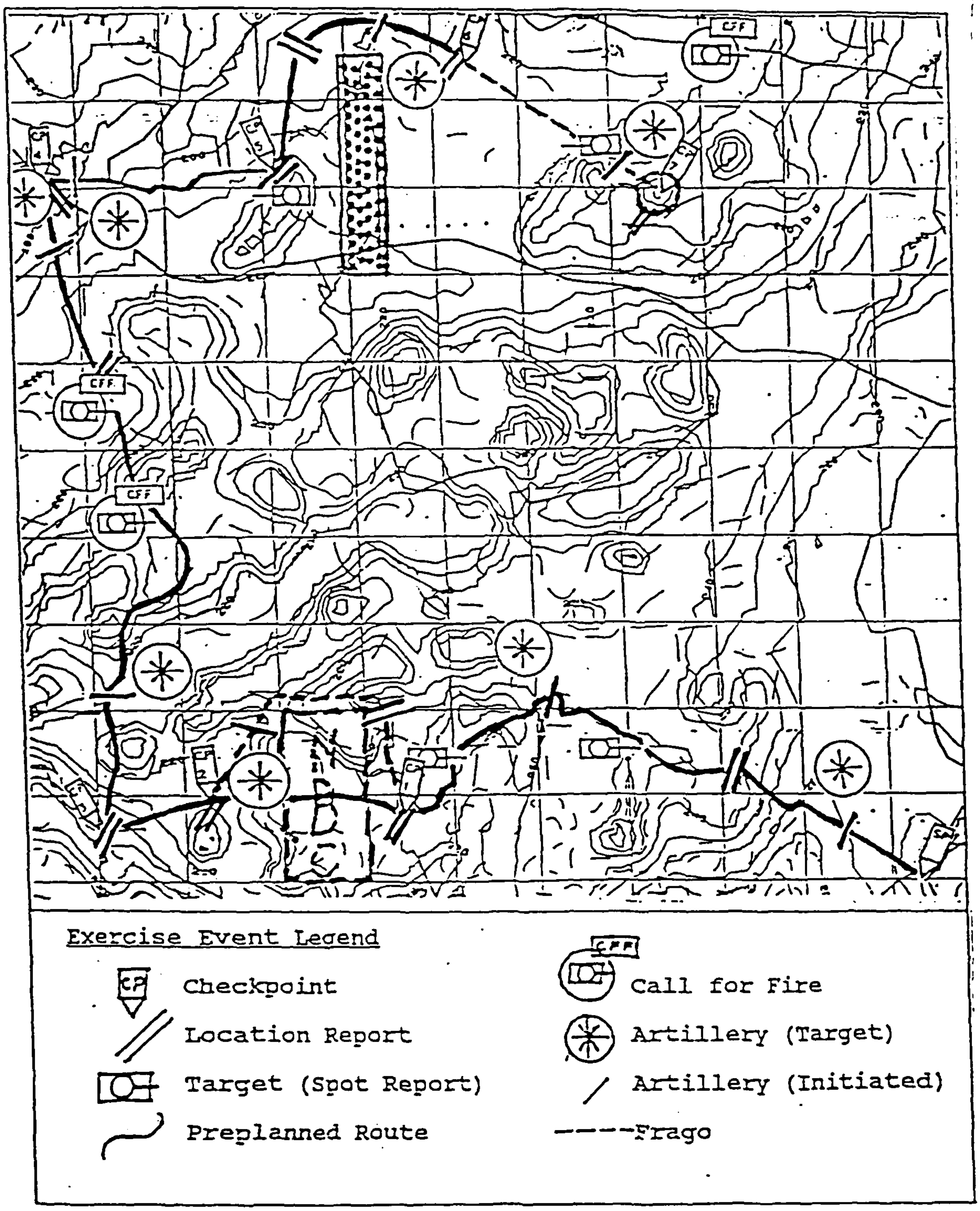


Figure 8. The Armor Small Unit $C^3$ Exercise map overlay (from Du Bois, 1989).

## Platoon Combat Missions

The platoon combat mission exercises used in this research required tank platoons to communicate, maneuver, and fight in a realistic and task loaded collective combat environment. Exercise development procedures closely paralleled those outlined by Du Bois and Smith (1989), as adapted from USAARMS field publications. Exercise development was also coordinated with SMEs from the USAARMS, DCD, and Armor units at Fort Knox. This coordination ensured that the combat missions developed were consistent with the latest changes in tactics, planning, and doctrine.

Generic mission overlays and OPORDS were drawn from two terrain board exercise combat missions used in the Armor Officer Basic Course. Both defensive and offensive missions were used to evaluate whether IVIS contributions to combat performance are consistent across both basic mission types. The particular missions chosen, Movement to Contact/Hasty Attack for the offensive mission and Hasty Defense for the defensive mission, have been rated as the missions most compatible with evaluation in SIMNET-D (Gound & Schwab, 1988). To model future battle conditions, at least two mission fragmentary orders (FRAGO) were included with each exercise.

Throughout both offensive and defensive combat mission execution, the platoons were required to perform several fundamental $C^3$ tasks. These tasks included: (a) reporting their own location; (b) reporting battlefield activities (SPOT reports), (c) reporting control measures (e.g., situation reports, checkpoint and phase line arrival reports), (d) reporting indirect fire activity (SHELL reports), (e) reporting enemy contact (e.g., CONTACT reports), (f) requesting indirect fire support (calls for fire), and (g) reacting to change of missions (FRAGOs).

In both missions, commanders were placed in demanding and fluid battlefield environments, requiring frequent navigational adjustments and effective $C^3$ and gunnery. To represent future battlefield conditions, enemy forces were simulated with the SAF to maintain a five-to-one or higher enemy to friendly vehicle ratio. Moreover, once platoons crossed the mission line of departure (LD), battlefield activities, including indirect fire attacks, target movements and fires, and higher commander orders and requests, occurred frequently. In fact, across the two and one-half hours each platoon was allowed for mission execution, the platoons were presented with over 60 critical battlefield events.

Although specifically developed to be realistic and demanding, the combat mission requirements in these SIMNET-D based scenarios differed from those of field-based scenarios in

at least two ways. First, the SAF-generated enemy vehicles were placed on the SIMNET-D battlefield with limited firing parameters (i.e., 500 meter or longer engagement ranges at the lowest firing accuracy status). These parameters were necessary because initial pilot testing efforts found that the default SAF acquisition and other firing parameters were too accurate--often resulting in long range friendly kills immediately upon enemy placement on the SIMNET-D battlefield.

Second, the SAF vehicle firing parameters resulted in a battlefield where enemy vehicles repeatedly fired at, but rarely destroyed, friendly units. The goal of this research was to evaluate small unit $C^3$ contributions of IVIS. Accurately modeling enemy vehicle firing capabilities proved very difficult using the SAF. Instead, an environment was chosen that would allow the accurate, objective, and, sometimes, automated collection of critical $C^3$ task performance measures across two and one-half hours per mission. Hence, when destroyed, friendly units were immediately reconstituted on the SIMNET-D battlefield. The degree to which IVIS affects battlefield survivability, only indirectly assessed in the current research, certainly deserves research attention. Until SAF simulation fidelity improves, however, battlefield survivability differences are probably best evaluated using manned enemy vehicles, operating in the field or in simulation.

The mission overlays for the offensive and defensive platoon combat missions are depicted in Figures 9 and 10, respectively. The OPORD, task requirements, FRAGO and other higher commander communications, and enemy unit and enemy indirect fire placements for the offensive combat mission are included in Appendix A. Defensive combat mission materials are included in Appendix B.

Other Instruments

The Armor small unit $C^3$ exercise and the offensive and defensive platoon combat missions were the primary measurement instruments for determining the performance contributions of IVIS to tank crew and platoon performance. As described in Table 2, however, nine additional instruments, including written knowledge tests, performance tests, and questionnaires, were also developed to support the current experiment. These instruments are described below and included in a separate ARI Research Note (Du Bois & Smith, in preparation).

Biographical Questionnaire. A biographical questionnaire was developed to gather a variety of background data from each soldier subject, including Armor experience, SIMNET-D experience, Conduct of Fire Trainer (COFT) experience, NTC experience, Armor education, and computer experience measures. As part of this questionnaire, soldiers signed a release form permitting the

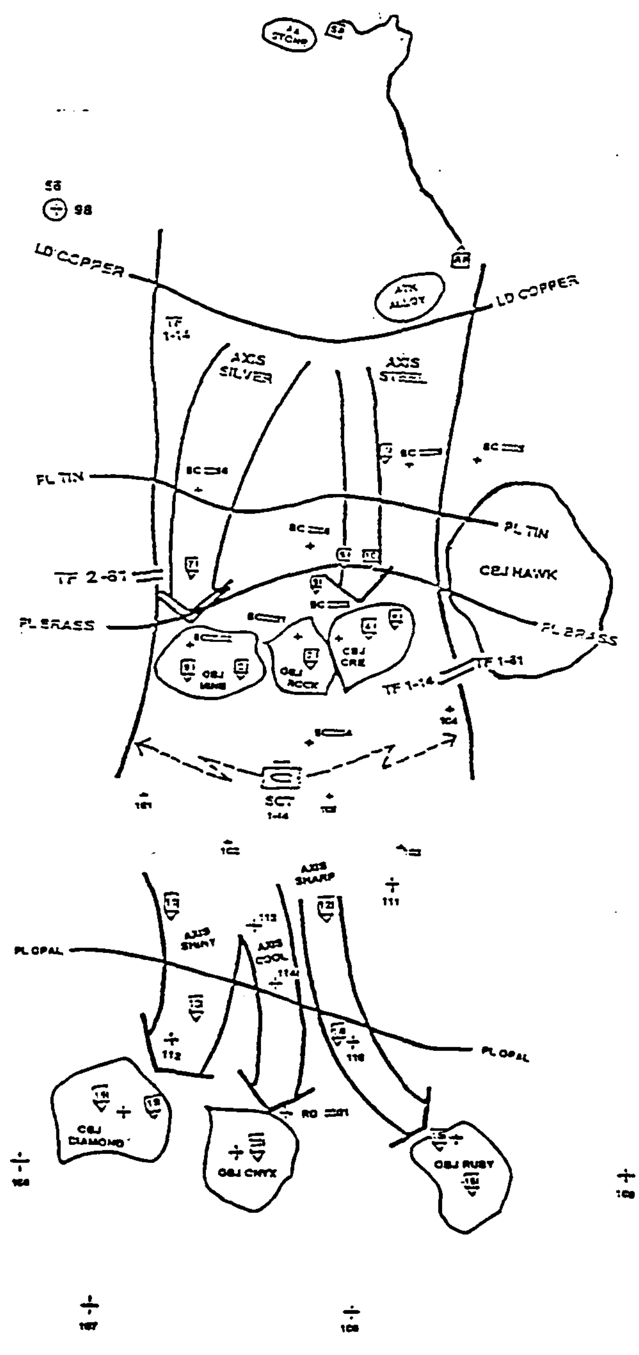


Figure 9. The Offensive Platoon Combat Mission map overlay.

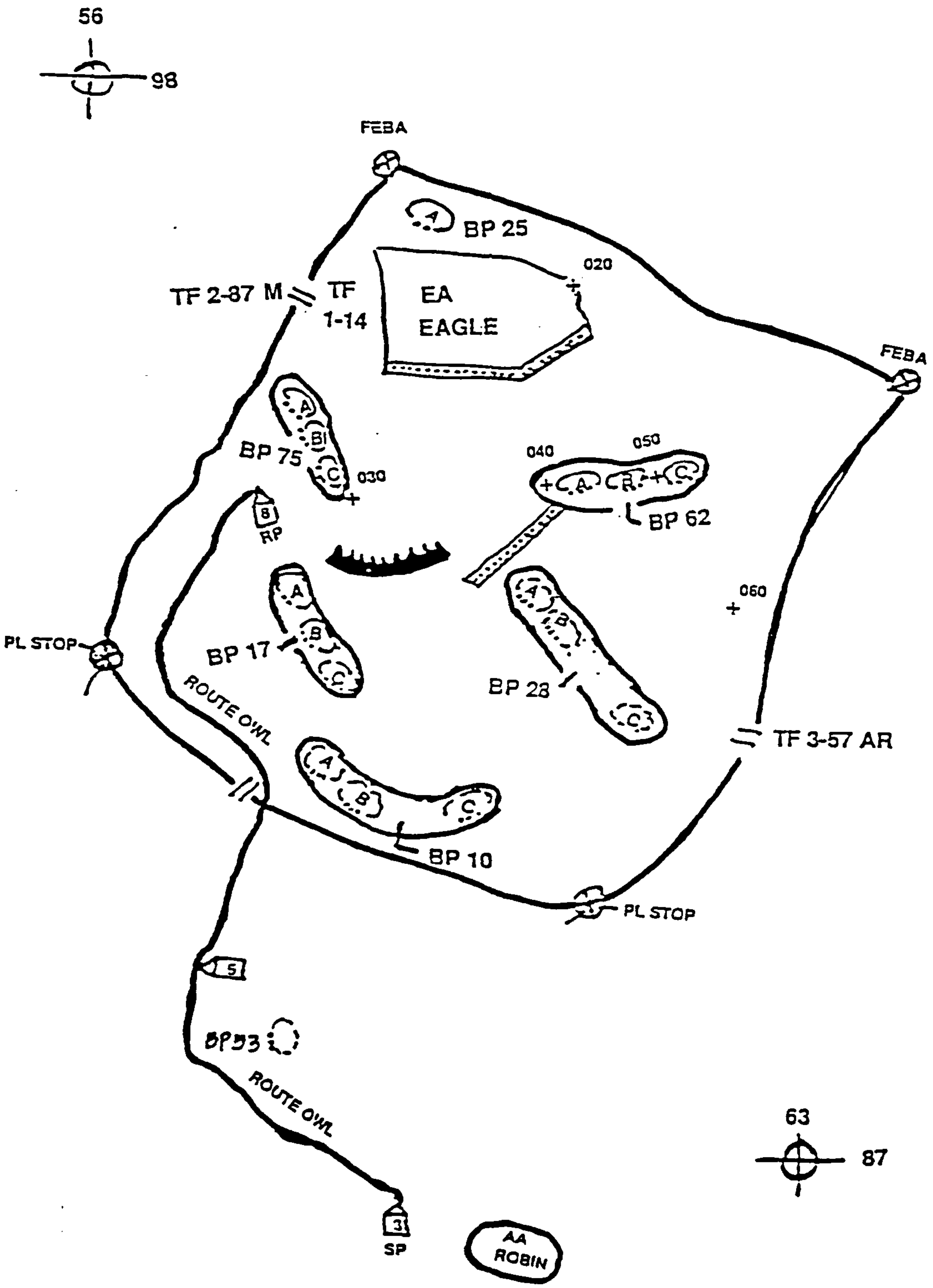


Figure 10. The Defensive Platoon Combat Mission map overlay.

research staff to obtain their Armed Services Vocational Aptitude Battery (ASVAB) scores. The biographical questionnaire and ASVAB release form used by Du Bois and Smith (1989) was modified for use in the current research. The biographical questionnaire served not only to describe the soldier subject sample, but also as a means to evaluate, post hoc, any systematic experience or aptitude differences between test groups not eliminated by treatment randomization.

Land Navigation Skills Test. To evaluate each tank crew member's map reading and land navigation skills, the Land Navigation Skills Test (LNST), developed by Du Bois and Smith (1989) was used. The 18-item exam assessed soldier proficiency in reading a protractor, determining map distances, locating a grid coordinate on a map, performing resection, intersection, and polar plots, reading a tank odometer, and identifying critical terrain features.

Navigation can be difficult to execute in SIMNET-D given the limited visual cues, closed hatch, and rotatable three vision block cupola of the M1 simulators. The LNST, like the biographical questionnaire, provided a means to evaluate, post hoc, test group navigation skill equivalence.

SIMNET-D Knowledge Test. The SIMNET-D Knowledge Test was a 16-item multiple choice exam. This instrument was developed to evaluate the SIMNET-D instruction used in the current research and to evaluate, post hoc, treatment group equivalence prior to testing. This test assessed soldier knowledge of critical SIMNET-D information, including differences between the real M1 tank and the M1 simulator, the operation requirements of the SIMNET-D Grid Azimuth Indicator and Turret Reference System, and visual system parameters.

SIMNET-D test items were initially drafted by the loader assistants, training instructors, and test administrators. Throughout pilot testing, soldier subjects and SMEs evaluated the draft items, suggesting item revisions and additions.

IVIS Knowledge Test. The IVIS Knowledge Test assessed tank commander knowledge of IVIS, including task execution procedures, function parameters, and display characteristics. Like the SIMNET-D Knowledge Test, IVIS test items were initially drafted by loader assistants, training instructors, and test administrators. At least one item was written for each of the tasks and functions supported by IVIS. Throughout pilot testing, soldier subjects and SMEs evaluated and revised the test items, as well as drafted additional items and item responses.

The IVIS Knowledge Test contained 40 multiple choice items. The test was designed to evaluate the degree to which commanders learned IVIS following the current research's experimental IVIS

training program. Consistently poor soldier performance on selected items, when supported by other IVIS training effectiveness and performance measures, could indicate critical IVIS training requirements and concerns.

IVIS Performance Test. The IVIS Performance Test was a 28-item hands-on test. This test assessed the ability of platoon and crew commanders to perform each of the functions supported by IVIS. At least one item was provided by each IVIS function, including navigation, map manipulation, and reporting functions. Each commander's performance for each task was rated by both the commander and the test administrator. Ratings were based on a seven-point task proficiency scale, with rating anchors ranging from not proficient (1) to expert (7). Raters were instructed to base their ratings on several factors, including the speed, accuracy, and ease by which commanders executed each task. The test administrator assigned to rate each commander was never the in-tank loader assistant assigned to that commander's tank crew.

Initial performance test items were drafted by the loader assistants, training instructors, and test administrators. Structured test forms and rating checklists were developed to support reliable evaluations. Throughout pilot testing efforts, soldier subjects evaluated and revised the test items, rating scale, and administration procedures. The IVIS Performance Test was designed to evaluate the current research's experimental IVIS training program and identify critical IVIS training requirements and concerns.

IVIS Training Reactions Questionnaire. The IVIS Training Reactions Questionnaire was a four-part questionnaire. It was designed to assess commander reactions to the current research's experimental IVIS training program and to identify critical IVIS training requirements and concerns.

In the first section, commanders rated the effectiveness of training provided for each of the functions supported by IVIS. In the second section, commanders rated the effectiveness of the training time allotted throughout the experimental IVIS training program for each IVIS function. For both the training effectiveness and training time ratings, commanders used a seven-point rating scale. Scale anchors ranged from extremely effective (1) to extremely ineffective (7) for the training effectiveness ratings and from considerable more time needed (1) to considerable less time needed (7) for the training time ratings. Both training effectiveness and training time ratings were collected for each IVIS function across the entire training program and by training phase, including the classroom training, research assistant practice, crew practice exercise, and platoon practice mission.

In section three, commanders rated 16 statements regarding the IVIS training program, including statements about the effectiveness of the loader assistants, training instructors, and classroom lecture materials. Commanders indicated their level of agreement with each statement using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The final section contained nine partial statements requiring commander completion. Commanders completed statements such as "The practice sessions with the research assistants could be improved by ______________________." Reactions questionnaire items were initially drafted by the loader assistants, training instructors, and test administrators. Throughout pilot testing, soldier subjects evaluated and revised the questionnaire items.

<u>IVIS Interface Questionnaire</u>. The IVIS Interface Questionnaire assessed soldier reactions to the IVIS interface design and other display characteristics. Soldier responses, coupled with performance and other data, were ultimately used to identify potential IVIS design and operation requirements.

The questionnaire contained five sections. In the first section, commanders indicated their level of agreement with 69 statements about the IVIS interface, such as "The location of the commander's IVIS display in the M1 simulator was acceptable." Soldiers rated each item using a five-point Likert scale. In the second, third, and fourth sections, commanders rated the ease-of-learning, ease-of-use, and helpfulness, respectively, of each of the functions supported by IVIS. Commanders used a seven-point scale for these ratings. For the ease-of-learning and ease-of-use ratings, scale anchors ranged from extremely easy (1) to extremely difficult (7). For the helpfulness ratings, scale anchors ranged from extremely helpful (1) to extremely unhelpful (7). In the final section, commanders completed six open-ended questions about the IVIS system. For example, commanders were asked to indicate the most and least beneficial IVIS functions and to recommend ways to improve IVIS.

IVIS questionnaire items were initially drafted by the loader assistants, test administrators, and Armor SMEs. Some items were adapted from questionnaires used in previous research (e.g., Du Bois & Smith, 1989; Lickteig, 1986; Schwab, 1987). The soldiers participating in the pilot test revised and evaluated these draft items.

<u>Task Difficulty Questionnaire</u>. The Task Difficulty Questionnaire, adapted from Du Bois and Smith (1989), required commanders to assess the difficulty they experienced performing 27 $C^3$ tasks. Commanders rated the difficulty they experienced in SIMNET-D (in their test condition) and the average difficulty of those tasks in the real tank (based on field experiences). Ratings were collected using a seven-point scale, with anchors ranging from extremely easy (1) to extremely difficult (7).

The questionnaire was primarily designed to evaluate differences in task difficulty or workload resulting from operating with IVIS. However, the task difficulty data could also indicate potential IVIS training requirements and concerns.

SIMNET-D Questionnaire. A short two-part questionnaire, the SIMNET-D Questionnaire, assessed soldier reactions to the use of SIMNET-D for evaluating IVIS and other Armor combat developments. In the first section, commanders rated their level of agreement with respect to five statements about SIMNET-D breakdowns and fidelity. In the second section, commanders completed five open-ended questions about SIMNET-D's limitations, advantages, and new equipment evaluation usefulness.

## Training and Testing Procedures

Using the between-groups design described earlier in Figure 7, four tank crews, one tank platoon, were trained and evaluated during each week of the current evaluation. The training and evaluation process occurred across four days and is outlined on an hour-by-hour basis in Table 4.

### Crew and Platoon Training Program

Overall, the training program occurred during four phases across Day One and the morning of Day Two for each week of the current research. These phases included orientation, classroom, hands-on, and formal practice sessions. The exact nature of the training--although generally similar with regard to training media and learning principles used--differed in content, depending on the experimental condition to which the platoon was assigned. In both conditions, training scripts and structured checklists were used by the instructors.

Orientation Phase. During the first phase of training, the tank crews were given an overview of the SIMNET-D program and the current research objectives. This overview included a description of the current experiment, the presentation of a SIMNET-D videotape, and a seat-specific orientation on the M1 simulator. The seat-specific orientation was conducted by the research assistants and was designed to familiarize crew members with the differences between the SIMNET-D M1 crew positions and actual M1A1 or M60A3 crew positions. For the crews in the IVIS condition, this orientation also included a short hands-on introduction to the IVIS, including a quick walk-though of major IVIS commander's and driver's display functions. As part of this training phase, each crew member completed the Biographical Questionnaire, LNST, and a Task Difficulty Questionnaire. For this task difficulty assessment, commanders rated the difficulty of performing $C^3$ tasks in the real tank in the field.

Table 4

Training and Testing Procedures

| Day | Time | Description | Location |
|---|---|---|---|
| 1 | 0800-1000 | SIMNET-D/Test Overview | SIMNET-D Classroom |
| | 1000-1020 | Break | |
| | 1020-1100 | Seat Specific Orientation | SIMNET-D M1s |
| | 1100-1200 | Classroom Lecture | SIMNET-D Classroom |
| | 1200-1300 | Lunch | |
| | 1300-1520 | Hands-On Practice | SIMNET-D M1s |
| | 1520-1540 | Break | |
| | 1540-1700 | Small Unit $C^3$ Exercise Practice | SIMNET-D M1s |
| 2 | 0800-1000 | Platoon Combat Mission | SIMNET-D M1s |
| | 1000-1020 | Break | |
| | 1020-1200 | After Action Review/ IVIS Training Evaluation | SIMNET-D Classroom |
| | 1200-1300 | Lunch | |
| | 1300-1700 | Small Unit $C^3$ Exercise (Session #1: Two Crews) | SIMNET-D M1s |
| 3 | 0800-1200 | Small Unit $C^3$ Exercise (Session #2: Two Crews) | SIMNET-D M1s |
| | 1200-1300 | Lunch | |
| | 1300-1700 | Platoon Combat Mission | SIMNET-D M1s |
| 4 | 0800-1200 | Platoon Combat Mission | SIMNET-D M1s |
| | 1200-1300 | Lunch | |
| | 1300-1700 | Debriefing/Questionnaires | SIMNET-D Classroom |

Classroom Phase. Following the orientation phase of training, the tank crews in the control condition received classroom instruction on adapting to the $C^3$ and navigational techniques unique to SIMNET-D (e.g., how to effectively use the SIMNET-D tank-based azimuth indicator and turret reference system). The crews in the IVIS condition received the same lecture but also received classroom instruction on using the IVIS system for $C^3$ and navigation. This training emphasized when, how, and why the crews should use the IVIS device.

For both conditions, the classroom instruction was supported by numerous lecture aids, including hand out materials (e.g., SIMNET-D M1 operator manuals, user guides, SIMNET-D paper maps, IVIS screen transparencies, and briefing slides). The Armor small unit $C^3$ exercise and platoon combat missions, particularly their administration procedures, were also described to each tank crew.

Hands-On Phase. During the third or hands-on phase of training, crews received an opportunity to practice operating the SIMNET-D M1 tank and to try using the $C^3$ and navigational resources available to them. Crews in the control condition practiced conventional $C^3$ and navigation tasks, including using the grid azimuth indicator, turret reference system, SIMNET-D paper maps, and SIMNET-D radios to determine and report their own location, enemy activity, and shellings. In addition to practicing the use of the grid azimuth indicator, turret reference system, radios, and paper maps, the commanders in the IVIS condition also practiced using IVIS functions to complete the same $C^3$ tasks.

Research assistants, using structured scripts and task lists, conducted this hands-on training for crews in both conditions. A test controller, located at a PVD and SAF station, controlled battlefield events, supervised crew training, and transmitted specific performance feedback, such as actual vehicle grid coordinates to each commander. Assistants were trained to have each crew complete each training task at least three times or until the soldiers indicated that they understood and were comfortable with the task requirements and standards.

Formal Practice Phase. The final or formal practice phase of training provided the crews in both conditions with an opportunity to complete a practice Armor small unit $C^3$ exercise and, as a platoon, a practice combat mission. Both the practice $C^3$ exercise and combat mission were similar to, but about half as long as, the actual test exercises. The practice $C^3$ exercise required performance of each Armor small unit $C^3$ task included in the actual exercise, except the battle position task, at least once. The practice combat mission was an offensive Movement to Contact/Hasty Attack mission and included no change of mission orders. The practice combat mission allowed the platoon and crew

commanders to perform $C^3$ tasks and to integrate combat performance requirements in a collective combat environment.

Throughout both practice exercises, the assistants and controllers provided timely, specific, performance-based feedback to the crewmen to promote retention and transfer of the material taught during the earlier training phases. For example, when commanders transmitted battlefield reports, the test controller would often tell the commander the actual grid location and how far off, in meters, their reported grid deviated from the actual grid.

Following each practice exercise, the crew members met for a group discussion and feedback session with the test controllers and research assistants. This session focused on providing the soldiers with specific feedback on their exercise performance and final instruction on actual testing requirements. Crew members were also urged to express their reactions to the training program. Following the practice platoon exercise, all crew members completed the SIMNET-D Knowledge Test. The commanders in the IVIS condition also completed the IVIS Knowledge Test, IVIS Performance Test, and IVIS Training Reactions Questionnaire.

### Armor Small Unit $C^3$ Exercise Administration

Immediately following training, the four crews were assigned a time to complete the $C^3$ exercise (either p.m. Day Two or a.m. Day Three). SIMNET-D resources provided, including two PVDs, an SAF station, MCC, and three radios, allowed up to two crews to complete the exercise in a time-lagged fashion. That is, after one of the two crews had completed about one-third of the exercise (i.e., reached checkpoint 1), the second crew was given its orders and began planning its mission. Two crews completed the exercise in the afternoon of Day Two. The remaining two crews completed the exercise in the morning of Day Three. Unless soldier commitments dictated otherwise, crews were randomly assigned to exercise sessions.

Immediately before each tank crew began, each commander was given an order for the $C^3$ exercise, including a map overlay (essentially a road march course), a protractor, and a grease pencil. For IVIS-equipped commanders, a march map graphic was also overlaid onto the IVIS map display. Similar mission graphics, transmitted via IVIS, accompanied each FRAGO for IVIS-equipped commanders. Commanders in the control or NO IVIS condition, however, only received conventional, strictly verbal, FRAGOs. For FRAGO missions, each commander, with his crew, could leave his tank to plan the new mission.

After receiving the $C^3$ exercise order, each commander, with his crew, was allowed to plan the mission. No time limits were

placed on this planning time, but the importance and danger of their upcoming mission was stressed. Before actually beginning their mission, however, commanders were required to report when they had completed their planning. Although a few crews took longer than the four hours allotted for exercise completion, all crews did complete the $C^3$ exercise. Each crew was given a 15-minute break during the exercise.

## Offensive and Defensive Platoon Combat Mission Administration

The offensive and defensive platoon combat missions were administered on the p.m. of Day Three and the a.m. of Day Four. As part of each mission, the platoons were given a 15-minute operations order (OPORD) briefing by the test administrators. After the OPORD briefing, the platoon and crew commanders, with their crews, were allotted 30 minutes to plan their mission. If necessary, planning time was increased until the commanders were satisfied with their planning efforts and ready to execute the mission. Each commander was given a SIMNET-D paper map with a mission overlay, a protractor, and a grease pencil for use in planning and executing each mission. All platoon leaders were also given copies of the mission OPORD and were urged to refer to them during the combat exercises when necessary.

For commanders in the IVIS condition, mission graphics were overlaid onto the IVIS map display. Moreover, similar mission graphics, transmitted via IVIS, also accompanied each FRAGO for IVIS-equipped platoon leaders. Platoon leaders could relay these graphics, using IVIS, to their crew commanders. Platoon commanders in the control or NO IVIS condition, however, only received conventional, strictly verbal, FRAGOs. For FRAGO missions, the platoon and crew commanders in both conditions, if desired, could leave their tanks to plan their new mission.

Each platoon was allowed two and one-half hours to execute each combat mission. Mission administration order was counterbalanced across treatment conditions. Each platoon was given a 15 minute break during each mission. Immediately following each mission, the platoons were also given an after action review of their mission performance, including a description of their mission movement route and unit formations, radio and/or IVIS communication patterns and problems, and target acquisition, gunnery, and $C^3$ performance.

## Soldier Debriefing and Feedback

Following testing, p.m. Day Four, the crew members were debriefed on the objectives of the current experiment and were urged to express their reactions to the research. Questions and comments by the crew members were addressed as completely as

possible. Crew members were also given instructions for obtaining a copy of the experiment's technical report upon completion of the evaluation, if they desired.

As part of this debriefing session, each commander completed the Task Difficulty Questionnaire, IVIS Interface Questionnaire, IVIS Performance Test, and SIMNET-D Questionnaire. The additional IVIS Performance Test administration after the exercises provided an opportunity to assess commander IVIS proficiency after each commander had acquired additional experience with IVIS. The IVIS Performance Test was never administered by the same research assistant or training instructor who had conducted the commander's post-training IVIS performance assessment. For the post-testing task difficulty assessment, commanders rated the difficulty of performing each of 27 $C^3$ tasks in their SIMNET-D test condition, as well as estimated the difficulty of these same tasks when performed in a real tank in the field.

## Criterion Measures

### Crew and Platoon Performance Measures

SIMNET-D Criterion Measure Generation Capabilities. The vehicle appearance, vehicle status, and indirect and direct firing event data broadcast by SIMNET-D simulators and MCC are necessary to support SIMNET-D's distributive network. However, these packets, as well as event flags directed from the PVD, can be collected, combined, and analyzed to generate many critical $C^3$ and other soldier performance measures. The current research exploits this capability and, as a result, evaluates several measures too costly or dangerous to collect in the field.

For example, a critical $C^3$ requirement of small unit Armor commanders is the preparation and transmission of battlefield reports, including reports of enemy vehicle locations (contact and spot reports) and shellings (shell reports), as well as requests for indirect fire support (call for fire (CFF) and CFF adjustment requests). The speed and accuracy with which commanders send these reports is critical to mission success.

In the current research, SIMNET-D's vehicle appearance data packets are used to verify the accuracy of reported own-vehicle, target, and shelling grid locations, as well as initial and subsequent indirect fire missions. Vehicle appearance and status packets also support the evaluation of the unit dispersion, velocity, distance travelled, and fuel consumption measures, while firing event data packets support measures of target engagement range (an approximation of acquisition range.)

Moreover, test administrators marked critical battlefield events (e.g., target engagements, shellings, fire missions, checkpoint arrivals, phase line crossings, etc.) with PVD based event flags to generate other measures. These measures included the speed with which reports follow the assessment of respective battlefield stimuli and the time units required to plan and execute selected battlefield tasks. Structured data collection checklists, in-tank data collectors, and FM radio voice recordings were also used to evaluate the accuracy of each report's format and content, as well as soldier process measures such as commander vision block, paper map, and IVIS usage ratings.

Criterion Measure Generation. The Armor crew and platoon $C^3$ and other performance measures selected for collection in SIMNET-D were identified by the SMEs and researchers. First, numerous Armor $C^3$ task analyses and other sources of Armor task standards (e.g., Wheaton, Allen, Johnson, Drucker, Ford, & Campbell, 1980), as well as the criterion measures used in previous $C^3$ research (e.g., Du Bois & Smith, 1989; Gound & Schwab, 1988; Schwab, 1987), were reviewed.

A preliminary list of potential $C^3$ measures for each $C^3$ task was then prepared and reviewed by SMEs. The research staff also evaluated the capability to collect each measure using SIMNET-D resources. The results of exercise pre-testing, including soldier comments, aided in selecting final lists of crew and platoon $C^3$ and other performance measures. These crew and platoon measures are defined in Tables 5 and 6, respectively.

Measurement Concerns. Evaluating the multiple performance measures associated with each task raises a number of challenging issues, including task contingencies, criticality, and standards. First, evaluating each measure in isolation can result in some faulty interpretations, especially when "successful" performance on one task measure is contingent on "successful" performance on an ancillary task measure. For instance, once a tank commander directs his crew through an NBC or minefield area (a mistake that would likely cost lives on a real battlefield), the "time to execute bypass" measure becomes meaningless. Regardless of how quickly a commander executed the bypass, he made a costly--if not fatal--mistake, and his score should indicate that.

Similar problems arise in other $C^3$ tasks evaluated. For example, a spot report which, although sent rapidly with correct "what" and "count" components, includes a grid over 1,000 meters away from the actual target location, provides potentially misleading information to a higher-level commander. Moreover, a commander who rapidly executes and plans a battle position task but sets up final fighting positions at the wrong location has jeopardized his unit and performed poorly.

Table 5

Armor Small Unit $C^3$ Exercise Performance Measures

| Construct | Performance Measures |
|---|---|
| <u>Command, Control, and Communication Performance</u> | |
| React to a change of mission | Number of fragmentary orders (FRAGOs) successfully executed.<br>Time to plan FRAGOs in minutes.<br>Time to execute FRAGOs in minutes. |
| Bypass obstacles | Number of obstacle bypasses successfully executed.<br>Time to execute bypass in minutes. |
| Issue calls for fire (CFFs) | Accuracy of initial CFF in meters.<br>Time to reach effect* in minutes.<br>Number of CFFs used to reach effect.<br>Number of CFF tasks for which target effect was reached. |
| Report own location | Accuracy of grid reported in meters.<br>Time to report location in seconds. |
| Report control measures | Accuracy of grid reported in meters. |
| Report enemy contact (CONTACT reports) | Accuracy of report "what" component.<br>Accuracy of report "where" component.<br>Number of reports sent. |
| Report battlefield activity (SPOT reports) | Accuracy of grid reported in meters.<br>Accuracy of report "what" component.<br>Accuracy of report "count" component.<br>Time to report activity in seconds.<br>Number of reports sent. |
| Report indirect fire activity (SHELL reports) | Accuracy of grid reported in meters.<br>Time to report activity in seconds.<br>Number of reports sent. |
| Select and occupy a battle position (BP) | Time to plan BP task in minutes.<br>Time to execute BP task in minutes.<br>Success of BP task (yes or no). |

*Target effect is reached when a CFF grid is within 200 meters of a target. Commanders were allowed up to six CFFs per CFF task.

Table 5 (continued)

Armor Small Unit $C^3$ Exercise Performance Measures (Continued)

| Construct | Performance Measures |
|---|---|
| <u>General Mission Performance</u> | |
| Execute Mission | Time to plan exercise in minutes.<br>Time to execute exercise in minutes.<br>Distance travelled in kilometers.<br>Fuel used in gallons.<br>Velocity (overall and while moving).<br>Tank velocity while moving. |
| Acquire Targets | Range of target engagements in meters. |
| Resource Usage** | Percent of time the commander used vision blocks; paper map; IVIS. |

**These measures are based on commander and research assistant ratings. The IVIS rating only applies to IVIS commanders.

Besides not taking into account task measure contingencies, evaluating each task measure alone does not consider the importance of each measure. For example, the most vital role of a contact report is to inform a higher-level commander that one's unit has acquired enemy aircraft or vehicles. Although the reports should, according to current standards, include "what" is acquired (e.g., tanks) and "where" the enemy is located (e.g., north), modest misinformation is not as important as remembering to inform the commander that "CONTACT" has been made.

Finally, task assessment techniques must account for current military standards. For example, current standards require commanders to report graphic control measures and battlefield activity to within 200 meters and within 30 seconds. Hence, final performance measures selected should indicate commander performance with respect to these standards.

<u>Criterion-Oriented Composite Measures</u>. To resolve these concerns, composite performance measures were created for each $C^3$ task to reflect task performance contingencies, task measure criticality, and current military standards. These criterion-oriented composite measures were created for each task through a point assignment scheme in which performance on each task measure contributed points towards one's final overall task score.

Table 6

Platoon Combat Mission Performance Measures

| Construct | Performance Measures |
|---|---|
| Command, Control, and Communication Performance | |
| React to a change of mission | Number of fragmentary orders (FRAGOs) successfully executed.<br>Time to execute FRAGOs in minutes.<br>Time to plan FRAGOs in minutes. |
| Report own location and control measures | Accuracy of grid reported in meters.<br>Time to report grid in seconds. |
| Report enemy contact (CONTACT reports) | Number of reports sent. |
| Report battlefield activity (CFF and SPOT reports) | Accuracy of grid reported in meters.<br>Time to report activity in seconds.<br>Number of reports sent. |
| Report indirect fire activity (SHELL reports) | Accuracy of grid reported in meters.<br>Time to report activity in seconds.<br>Number of reports sent. |
| General Mission Performance | |
| Execute Mission | Percent of mission segments executed.<br>Time to complete mission in minutes.*<br>Distance travelled in kilometers.*<br>Fuel used in gallons.*<br>Velocity (overall and while moving).* |
| Unit Dispersion | Percent of time between section dispersion is above 500 meters.<br>Percent of time within section dispersion above 200, 500 meters. |
| Acquire Targets | Range of engagements in meters. |
| Resource Usage** | Percent of time the commander used vision blocks; paper map; IVIS. |

* These measures divided by the number of segments executed.
** These measures are based on commander and research assistant ratings. The IVIS rating only applies to IVIS commanders.

For example, at the crew level, the overall composite score for contact reports, CONTACT, results from performance on three task measures: (a) whether the report was sent (i.e., at least the keyword "CONTACT" was reported); (b) the accuracy of the report's "what" component; and (c) the accuracy of the report's "where" component. Each report required was worth up to five points. Three points were awarded for each report sent, and one point each was awarded for correct report "what" and "where" components. The overall CONREP score was simply the sum of the three component scores across all required reports.

Although Army task analyses and field manuals were used to support most measure scoring assignments, some task measure standards are not specified in these documents. In these instances, SMEs were necessary for determining appropriate scoring strategies. A summary of the criterion-oriented scoring strategies used for each of the crew and platoon $C^3$ tasks evaluated in the current research is contained in Appendix C and D, respectively. Differences between the scoring strategies used for crew and platoon $C^3$ task measurement reflect the different component measures collected across each unit level. The demands placed on exercise administrators and data collectors during the platoon missions did not allow the gathering of some of the less critical measures collected for the small unit commander $C^3$ exercise. Further information on the development and basis for criterion-oriented measures is contained in Du Bois (1989).

<u>Normative-Oriented Composite Measures</u>. In addition to generating criterion-oriented measures, normative-oriented composite measures were also generated for $C^3$ and other measures. These normative measures were based on the sum of the standard scores (Z scores) associated with each task or construct. For example, at the crew level, the overall normative composite score for contact reports, ZCONREP, is the sum of the standard scores for three component measures. These measures were: (a) the number of reports sent, (b) the number of reports sent with the correct "what" component, and (c) the number of reports sent with the correct "where" component. Normative-oriented composite scoring strategies for crew and platoon performance measures are included in Appendix E and F, respectively.

<u>IVIS Usage Measures</u>

To support the platoon performance evaluation, IVIS was instrumented to broadcast selected information across the SIMNET-D Ethernet. This information was all based on IVIS intervehicular reporting functions and allowed the generation of several IVIS usage measures. These measures included: (a) the number of reports sent, (b) the number of reports in the queue, (c) the percent of reports called up from the queue, and (d) the time to call reports up from the queue.

## Other Measures

The other instruments used in the current research provided additional measures for evaluating IVIS. The IVIS Knowledge Test, Performance Test, and Training Reactions Questionnaire, for example, provided individual and composite IVIS knowledge, proficiency, training effectiveness, and training time measures necessary for evaluating the experimental IVIS training program.

The Task Difficulty Questionnaire provided individual and composite ratings of the difficulty commanders experienced performing 27 $C^3$ tasks across the crew and platoon exercises. Difference score measures, examined for each task and overall, provided a means to evaluate the disparity in difficulty between $C^3$ tasks performed in SIMNET-D (with or without IVIS) and estimated the difficulty of these same tasks when performed in a real tank in the field.

The IVIS Interface Questionnaire provided several individual ratings for evaluating specific IVIS system features, as well as individual and composite ratings of the ease-of-learning, ease-of-use, and helpfulness of each IVIS function. The IVIS Interface Questionnaire and the SIMNET-D Questionnaire also provided commander responses to open-ended questions for evaluating IVIS and SIMNET-D, respectively.

## Privacy Procedures

Throughout the conduct of this research, including both the pilot and actual test administrations, the confidentiality of all soldier subject responses was maintained. Whenever possible, soldier subjects were identified by number. Soldier subjects were assured of the confidentiality of their responses and performance prior to completing any questionnaires and tests and participating in any SIMNET-D based exercises.

## Data Analyses

The data analyses were performed in six phases. First, soldier Armor experience, Armor education, ASVAB, and land navigation skills measures collected from the Biographical Questionnaire and LNST were analyzed. The purpose of these analyses was to describe the soldier subject sample and to evaluate, *post hoc*, the success of the treatment randomization procedure used in the current research. Multivariate analyses of variance (MANOVAs), with follow-up *t*-tests, were used to analyze continuous soldier background data. Chi-Square tests were used to evaluate categorical soldier background data.

Second, the crew performance data collected from the Armor Small Unit $C^3$ Exercise were analyzed to evaluate the effects of IVIS on crew performance. MANOVA, Discriminant Analysis (DA), and univariate homogeneity of variance tests, with follow-up *t*-tests, were performed to evaluate IVIS and NO IVIS group differences on the $C^3$ exercise performance measures. Separate analyses were performed to assess test group differences across the criterion-oriented composite measures, the normative-oriented composite measures, and less critical soldier behavior or process measures provided by SIMNET-D, but not necessarily related to effective $C^3$ performance (e.g., fuel consumption, distance travelled, tank velocity, target engagement range, and vision block usage measures).

Third, the offensive and defensive platoon combat mission data were analyzed. A partial repeated measures MANOVA with follow-up *t*-tests was performed for the offensive and defensive mission data. Separate analyses were conducted for the criterion and normative-oriented composites. Additional *t*-tests were also performed to evaluate group differences on several less critical mission performance measures, such as distance travelled, fuel used, and unit dispersion measures.

Next, the IVIS usage data, collected during the platoon combat missions, were analyzed. Descriptive analyses were conducted to examine commander IVIS usage patterns during both offensive and defensive missions.

Fifth, the IVIS training evaluation measures generated from the IVIS Knowledge Test, Performance Test, and Training Reactions Questionnaire were evaluated. Both descriptive and correlational analyses were conducted.

Finally, the questionnaire data collected from the SIMNET-D Questionnaire, IVIS Questionnaire, and Task Difficulty Questionnaire were surveyed using descriptive analyses and, for assessing group differences on the difficulty measures, *t*-tests.

## Results

### Group Equivalence Analyses

No significant differences were detected between the control (NO IVIS) and IVIS condition soldiers on any of the 15 continuous and categorical experience, education, knowledge, and aptitude measures collected. Ten continuous soldier measures evaluated included test tank position or job experience, NTC experience, Armor experience, last field exercise experience, SIMNET-D

experience, COFT experience, ASVAB Combat Orientation (CO) and General Technical (GT) scores, LNST score, and SIMNET-D Knowledge Test score. The five categorical measures evaluated included current tank position, Armor education, computer experience, military occupational specialty (MOS), and military grade. Table 7 presents the means and standard deviations by test condition, IVIS and NO IVIS, for each of the continuous measures collected.

Appendix G contains means and standard deviations, by tank position, for each continuous measure collected, as well as MANOVA and ANOVA findings.

Overall, the soldiers evaluated in this research possessed an average of about two years of experience in their test tank position and nearly six years of experience in Armor. Platoon leaders in both the IVIS and NO IVIS groups, however, possessed significantly less job experience--an average of only 7 months--than platoon sergeants, tank commanders, drivers, and gunners. Similarly, platoon leaders, on the average, possessed significantly less Armor experience.

Nevertheless, the platoon leaders, on the average, consistently outperformed the platoon sergeants, tank commanders, drivers, and gunners on the LNST. No difference in performance across test positions, however, was detected for the SIMNET-D Knowledge Test. The soldiers, on the average, correctly answered 94% or 15 of the 16 SIMNET-D Knowledge Test items.

On the average, the soldiers' had about 72 weeks without field training. Platoon sergeants, tank commanders, and gunners had significantly more recent field training experiences than platoon leaders and drivers. Furthermore, most of the soldiers had never been to NTC, had about three days of previous SIMNET-D experience, had about nine days of previous COFT experience, and possessed limited computer proficiency.

## Armor Small Unit $C^3$ Exercise Analyses

Table 8 presents the IVIS and NO IVIS condition means and standard deviations for each of the Armor $C^3$ exercise performance measures collected, including criterion and normative-oriented composite measures. Overall, commander performance was widely dispersed, particularly for those commanders in the control condition. Large standard deviations were especially apparent with the report accuracy and time measures, where standard deviations were nearly half their mean value.

Table 7

Soldier Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Soldier Measure | | Test Condition IVIS | Test Condition NO IVIS |
|---|---|---|---|
| Tank Job Experience (Months) | M | 22 | 25 |
| | SD | 19 | 30 |
| | N | 72 | 72 |
| Armor Experience (Months) | M | 66 | 71 |
| | SD | 46 | 59 |
| | N | 72 | 72 |
| Time Since Last Field Exercise (Weeks) | M | 57 | 86 |
| | SD | 46 | 59 |
| | N | 72 | 72 |
| NTC Experience (Rotations) | M | .83 | .50 |
| | SD | 1.13 | 1.20 |
| | N | 72 | 68 |
| SIMNET-D Experience (Hours) | M | 23 | 19 |
| | SD | 263 | 178 |
| | N | 71 | 72 |
| COFT Experience (Hours) | M | 94 | 44 |
| | SD | 263 | 178 |
| | N | 71 | 72 |
| ASVAB Combat Orientation Score | M | 110 | 108 |
| | SD | 11 | 12 |
| | N | 58 | 61 |
| ASVAB General Technical Score | M | 107 | 104 |
| | SD | 12 | 14 |
| | N | 60 | 63 |
| Land Navigation Skills Test | M | 10 | 10 |
| | SD | 4 | 4 |
| | N | 72 | 72 |
| SIMNET-D Knowledge Test Score | M | 15 | 15 |
| | SD | 1 | 1 |
| | N | 24 | 24 |

Table 8

Armor Small Unit $C^3$ Exercise Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **React to a change of mission or fragmentary order (FRAGO)** | | | |
| Number of FRAGOs | M | 1.8 of 2 | 0.9 of 2 |
| successfully executed | SD | 0.4 | 0.8 |
| Time to plan FRAGOs | M | 3min | 7min |
| in minutes | SD | 1min | 2min |
| Time to execute FRAGOs | M | 10min | 21min |
| in minutes | SD | 2min | 9min |
| FRAGO | M | 20 of 24 | 10 of 24 |
| criterion composite points | SD | 4 | 7 |
| ZFRAGO | M | +1.93 | -1.93 |
| normative composite z score | SD | 0.95 | 1.66 |
| **Bypass Obstacles** | | | |
| Number of bypasses | M | 1.0 of 2 | 0.6 of 2 |
| successfully executed | SD | 0.2 | 0.5 |
| Time to execute bypass | M | 9min | 22min |
| in minutes | SD | 1min | 10min |
| BYPASS | M | 18 of 20 | 10 of 20 |
| criterion composite points | SD | 5 | 7 |
| ZBYPASS | M | +1.24 | -1.24 |
| normative composite z score | SD | 0.69 | 1.68 |
| **Issue calls for fire** | | | |
| Accuracy of initial CFF | M | 127m | 832m |
| in meters | SD | 131m | 621m |
| Time to reach target effect* | M | 2min | 6min |
| in minutes | SD | 1min | 4min |

*Effect is reached when grid is within 200 meters of target.

Table 8 (Continued)

Armor Small Unit $C^3$ Exercise Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | Test Condition: IVIS | Test Condition: NO IVIS |
|---|---|---|---|
| **Issue calls for fire (Continued)** | | | |
| Number of CFFs used to reach effect | M | 1.2 | 3.7 |
| | SD | 0.6 | 1.3 |
| Number of CFFs tasks resulting in effect | M | 3 of 3 | 2.1 of 3 |
| | SD | 0.2 | 0.9 |
| CFF criterion composite points | M | 56 of 60 | 32 of 60 |
| | SD | 7 | 15 |
| ZCFF normative composite z score | M | +2.56 | -2.56 |
| | SD | 1.08 | 3.32 |
| **Report own location** | | | |
| Accuracy of grid reported in meters | M | 8m | 502m |
| | SD | 11m | 371m |
| Time to report location in seconds | M | 15sec | 69sec |
| | SD | 6sec | 32sec |
| LOCREP criterion composite points | M | 32 of 32 | 21 of 32 |
| | SD | 0.3 | 5 |
| ZLOCREP normative composite z score | M | +1.45 | -1.45 |
| | SD | 0.16 | 1.44 |
| **Report control measures** | | | |
| Accuracy of grid reported in meters | M | 22m | 433m |
| | SD | 25m | 325m |
| CPREP criterion composite points | M | 28 of 28 | 21 of 28 |
| | SD | 0.4 | 5 |
| ZCPREP normative composite z score | M | +0.67 | -0.67 |
| | SD | 0.08 | 2.28 |

Table 8 (Continued)

Armor Small Unit $C^3$ Exercise Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Report enemy contact (CONTACT reports)** | | | |
| Number of reports sent with correct "what" | M | 2.7 of 6 | 0.8 of 6 |
| | SD | 1 | 1 |
| Number of reports sent with correct "where" | M | 5 of 6 | 1.6 of 6 |
| | SD | 1.4 | 1.9 |
| Number of reports sent | M | 5 of 6 | 3.2 of 6 |
| | SD | 1.4 | 2 |
| CONREP criterion composite points | M | 23 of 30 | 12 of 30 |
| | SD | 6 | 8 |
| ZCONREP normative composite z score | M | +1.70 | -1.70 |
| | SD | 0.77 | 2.25 |
| **Report battlefield activity (SPOT reports)** | | | |
| Accuracy of grid reported in meters | M | 192m | 529m |
| | SD | 192m | 285m |
| Number of reports sent with correct "what" | M | 2.8 of 6 | 2.8 of 6 |
| | SD | 0.7 | 0.8 |
| Number of reports sent with correct "count" | M | 4.9 of 6 | 4.9 of 6 |
| | SD | 1.4 | 1.0 |
| Time to report activity in seconds | M | 51sec | 92sec |
| | SD | 22sec | 42sec |
| Number of reports sent | M | 5.1 of 6 | 5.3 of 6 |
| | SD | 1.4 | 0.9 |
| SPOTREP criterion composite points | M | 53 of 72 | 43 of 72 |
| | SD | 16 | 10 |
| ZSPOTREP normative composite z score | M | +1.22 | -1.22 |
| | SD | 1.80 | 2.22 |

Table 8 (Continued)

Armor Small Unit $C^3$ Exercise Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Report indirect fire activity** | | | |
| Accuracy of grid | M | 327m | 608m |
| reported in meters | SD | 142m | 262m |
| Time to report | M | 32sec | 87sec |
| activity in seconds | SD | 8sec | 68sec |
| Number of reports | M | 7.8 of 8 | 6.8 of 8 |
| sent | SD | 0.5 | 1.9 |
| SHELLREP | M | 58 of 80 | 32 of 80 |
| criterion composite points | SD | 10 | 11 |
| ZSHELLREP | M | +1.30 | -1.30 |
| normative composite points | SD | 0.69 | 2.28 |
| **Select and occupy battle positions** | | | |
| Time to plan | M | 3min | 6min |
| BP task in minutes | SD | 2min | 2min |
| Time to execute | M | 10min | 12min |
| BP task in minutes | SD | 4min | 5min |
| Percent of successful | M | 92% | 42% |
| commanders | SD | 28% | 50% |
| BP | M | 11 of 12 | 5 of 12 |
| criterion composite points | SD | 1 | 5 |
| ZBP | M | +0.79 | -0.79 |
| normative composite z score | SD | 1.40 | 1.39 |

Table 8 (Continued)

Armor Small Unit $C^3$ Exercise Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Execute mission** | | | |
| Time to plan exercise in minutes | M | 12min | 26min |
| | SD | 6min | 12min |
| Time to execute exercise in minutes | M | 87min | 183min |
| | SD | 11min | 41min |
| TIMEZ normative composite z score (exercise plan and execution times) | M | +1.43 | -1.43 |
| | SD | 0.55 | 1.09 |
| Distance travelled in kilometers | M | 33.4kms | 38.7kms |
| | SD | 2.0kms | 6.8kms |
| Fuel used in gallons | M | 67gal | 173gal |
| | SD | 24gal | 92gal |
| Velocity in kilometers/hour (overall) | M | 22kms/hr | 15kms/hr |
| | SD | 4kms/hr | 4kms/hr |
| Velocity in kilometers/hour (while moving) | M | 37kms/hr | 35kms/hr |
| | SD | 5kms/hr | 7kms/hr |
| Range of target engagements in meters | M | 762m | 830m |
| | SD | 142m | 255m |
| Percent of time used vision blocks | M | 37% | 50% |
| | SD | 10% | 11% |
| Percent of time used paper map | M | 11% | 50% |
| | SD | 6% | 11% |
| Percent of time used IVIS | M | 52% | n/a |
| | SD | 11% | n/a |

Table 8 (Continued)

Armor Small Unit $C^3$ Exercise Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Global reporting measures** | | | |
| OWNREP | M | +1.53 | -1.53 |
| criterion composite z score | SD | 0.11 | 1.42 |
| (reporting own location and control measures) | | | |
| ZOWNREP | M | +2.11 | -2.11 |
| normative composite z score | SD | 0.21 | 1.97 |
| (reporting own location and control measures) | | | |
| OTHERREP | M | +1.73 | -1.73 |
| criterion composite z score | SD | 1.62 | 1.64 |
| (contact, spot, and shell reports) | | | |
| ZOTHERREP | M | +2.11 | -2.11 |
| normative composite z score | SD | 0.21 | 1.97 |
| (contact, spot, and shell reports) | | | |

Note. Individual *t*-tests for each submeasure were significant ($p<.05$) for all but four measures: (a) spot reports sent; (b) spot report "what" accuracy; (c) spot report "count" accuracy; and (d) battle position task execution time.

Criterion-Oriented Composite Measure Analyses.

To evaluate group differences on the $C^3$ measures collected, three separate MANOVAs, with follow-up *t*-tests and discriminant analysis (DA), were conducted. The first MANOVA, *t*-test, and DA analyses evaluated group differences on the criterion-oriented composite measures (i.e., OWNREP, OTHERREP, CFF, FRAGO, BYPASS, and BP), as well as the exercise planning and execution time composite measure (TIMEZ). Composite, rather than individual measures, were selected for MANOVA analyses to limit the variable-to-sample size ratio. The results of these analyses are shown in Table 9.

Table 9

Armor Small Unit $C^3$ Exercise Criterion-Oriented Measures: MANOVA, t-test, DA, and Univariate Homogeneity of Variance Analyses

| Analyses | Findings | | | |
|---|---|---|---|---|
| **MANOVA** | Test Name | Value | Approx. F | Sig. of F |
| Test Group | Pillais | 0.84 | 35.84 | <.001* |
| Main Effects | Hotellings | 5.24 | 35.84 | <.001* |
| | Wilks | 0.16 | 35.84 | <.001* |

| | | | |
|---|---|---|---|
| **t-tests** | Measure | t Value | Sig. of t |
| Test Group Mean | TIMEZ | -11.50 | <.001* |
| Differences | OWNREP | -10.55 | <.001* |
| | OTHERREP | -7.33 | <.001* |
| | CFF | -7.15 | <.001* |
| | FRAGO | -6.22 | <.001* |
| | BP | -5.73 | <.001* |

| | | | | | |
|---|---|---|---|---|---|
| **DA** | f(x) | Eigenvalue | %VAR* | Wilk's | p |
| Test Group Classification | 1 | 5.24 | 100% | .16 | <.0001* |

| | Measure | Canononical Coefficient | Within-Group Correlation |
|---|---|---|---|
| | TIMEZ | .69 | .74 |
| | OWNREP | .32 | .68 |
| | OTHERREP | .22 | .47 |
| | CFF | .16 | .46 |
| | FRAGO | .16 | .40 |
| | BP | .08 | .37 |

* All cases successfully classified by group.

| | | Cochran's C | | Bartlett-Box F | |
|---|---|---|---|---|---|
| **Univariate Homogeneity of Variance Tests** | Measure | Value | p | Value | p |
| | TIMEZ | .80 | .002* | 9.99 | .002* |
| | OWNREP | .99 | <.001* | 83.74 | <.001* |
| | OTHERREP | .51 | .943 | .01 | .943 |
| | CFF | .82 | .001* | 11.67 | .001* |
| | FRAGO | .79 | .002* | 9.48 | .002* |
| | BP | .93 | <.001* | 31.54 | <.001* |

*statistically significant ($p<.05$)

On every measure evaluated in these analyses, the IVIS-equipped crews performed significantly better than the crews using conventional $C^3$ tools and procedures. In fact, the DA resulted in one discriminant function which, based on crew scores, perfectly classified the 48 crews into their correct test condition. These group differences were strongest for the TIME and OWNREP composite measures. These composites correlated .74 and .68 with the DA function, while the OTHERREP, CFF, FRAGO, and BP function correlations were .47, .46, .40, and .37, respectively.

IVIS-equipped crews not only performed better, on the average, than crews without IVIS, but they also performed more consistently on all but one measure. Performance measure standard deviations for all but the OTHERREP measure were significantly smaller for the IVIS-equipped crews, as demonstrated by the Cochran's C and Bartlett's Box-F analysis findings (see Table 9).

## Normative-Oriented Composite Measure Analyses

The second MANOVA, *t*-test, DA, and univariate homogeneity of variance analyses evaluated group differences on the normative-oriented composite measures (i.e., ZOWNREP, ZOTHERREP, ZCFF, ZFRAGO, ZBYPASS, and ZBP) and the exercise planning and execution time composite (TIMEZ). The results of these analyses are summarized in Table 10.

Overall, crews with IVIS performed better than crews without IVIS on every normative-oriented composite measure evaluated. As with the criterion-oriented composite measure analyses, group differences were strongest with the own location reporting and planning and execution time composite measures (ZOWNREP and TIMEZ).

These differences were also quite large, allowing one discriminant function to successfully classify all cases. Based only on each crew's scores on the six composite measures, the discriminant function perfectly predicted whether the crews were in the IVIS or NO IVIS condition.

As with the criterion-oriented measures, the IVIS-equipped crews also performed more consistently than the crews without IVIS. The standard deviations for all but the ZBP composite were significantly smaller for the IVIS-equipped crews.

Table 10

Armor Small Unit $C^3$ Exercise Normative-Oriented Measures: MANOVA, *t*-test, DA, and Univariate Homogeneity of Variance Analyses

| Analyses | Findings | | | |
|---|---|---|---|---|
| **MANOVA** | Test Name | Value | Approx. F | Sig. of F |
| Test Group | Pillais | 0.83 | 33.37 | <.001* |
| Main Effects | Hotellings | 5.01 | 33.37 | <.001* |
| | Wilks | 0.17 | 33.37 | <.001* |

| Analyses | Measure | t Value | Sig. of t |
|---|---|---|---|
| ***t*-tests** | | | |
| Test Group Mean Differences | ZTIMEZ | -11.50 | <.001* |
| | ZOWNREP | -10.45 | <.001* |
| | ZOTHERREP | -6.95 | <.001* |
| | ZCFF | -7.18 | <.001* |
| | ZFRAGO | -9.89 | <.001* |
| | ZBP | -6.89 | <.001* |

| Analyses | f(x) | Eigenvalue | %VAR* | Wilk's | *p* |
|---|---|---|---|---|---|
| **DA** Test Group Classification | 1 | 5.01 | 100% | .17 | <.0001* |

| Measure | Canononical Coefficient | Within-Group Correlation |
|---|---|---|
| TIMEZ | .63 | .76 |
| OWNREP | .28 | .69 |
| OTHERREP | .32 | .47 |
| CFF | .05 | .52 |
| FRAGO | .33 | .64 |
| BP | -.13 | .45 |

*All cases successfully classified by group.

| Analyses | Measure | Cochran's C Value | Cochran's C *p* | Bartlett-Box F Value | Bartlett-Box F *p* |
|---|---|---|---|---|---|
| **Univariate Homogeneity of Variance Tests** | TIMEZ | .81 | .001* | 10.35 | .001* |
| | OWNREP | .99 | <.001* | 71.31 | <.001* |
| | OTHERREP | .82 | .001* | 11.67 | .001* |
| | CFF | .90 | <.001* | 22.37 | <.001* |
| | FRAGO | .75 | .010* | 6.60 | .010* |
| | BP | .51 | .900 | .02 | .901 |

* statistically significant ($p<.05$)

behavioral or outcome data not necessarily related to effective $C^3$ exercise performance. For example, using less fuel, travelling less distance, or engaging targets at longer ranges does not necessarily imply effective crew $C^3$ performance. These analyses are summarized in Table 11.

Overall, significant group differences were indicated on all but two measures: mean velocity on the move (VELMOVE) and mean target engagement range (HITRANGE). These differences showed that IVIS-equipped crews travelled less distance, used less fuel, maintained higher average velocities, looked out their vision blocks and sights less, and used the paper map less to execute the $C^3$ exercise. The differences in average velocity (VELMEAN) showed that IVIS-equipped crews spent less time at a halt than the crews using conventional $C^3$ tools and procedures.

These differences were also sufficiently large to allow a single discriminant function to correctly predict all but one crew's IVIS or NO IVIS status based solely on their process measure scores. Like the criterion and normative-oriented composite performance measure findings, crew performance with IVIS was more consistent than NO IVIS crew performance for most of the process measures. Crew performance with IVIS was significantly more consistent (i.e., smaller standard deviations were obtained) for the fuel used, distance travelled, engagement range, and paper map usage measures. No significant performance standard deviation differences were detected for the velocity measures and the vision block usage measure.

## Platoon Combat Mission Analyses

The IVIS and NO IVIS condition means and standard deviations for each of the offensive and defensive platoon combat mission performance measures collected are included in Tables 12 and 13, respectively. Like the crew $C^3$ exercise measures, these mission measures showed wide variance, particularly for the NO IVIS platoons. This variability was especially apparent with unit dispersion and report accuracy and time measures, where standard deviations reached values about half their mean values.

### Criterion-Oriented Composite Measure Analyses

To evaluate group differences on the offensive and defensive platoon mission measures collected, two separate sets of analyses were performed. First, a partial repeated measures MANOVA with follow-up *t*-tests was conducted to evaluate test group and mission differences on the criterion-oriented measures (i.e., OWNREP, OTHERREP, and FRAGO), as well as exercise execution time and mission completion measures (TIME and DONE, respectively). Composite, rather than individual measures, were selected for

Table 11

Armor Small Unit $C^3$ Exercise Process Measures: MANOVA, *t*-test, DA, and Univariate Homogeneity of Variance Analyses

| Analyses | Findings | | | | |
|---|---|---|---|---|---|
| **MANOVA** | Test Name | Value | Approx. F | Sig. of F | |
| Test Group | Pillais | 0.94 | 80.65 | <.001* | |
| Main Effects | Hotellings | 14.86 | 80.65 | <.001* | |
| | Wilks | 0.06 | 80.65 | <.001* | |
| ***t*-tests** | Measure | t Value | Sig. of t | | |
| Test Group Mean | DISTANCE | 3.68 | .001* | | |
| Differences | FUEL | 5.44 | <.001* | | |
| | VELMEAN | -5.99 | <.001* | | |
| | VELMOVE | -1.09 | .281 | | |
| | HITRANGE | 1.14 | .261 | | |
| | VBS | 4.33 | <.001* | | |
| | MAP | 14.84 | <.001* | | |

| Analyses | f(x) | Eigenvalue | %VAR* | Wilk's | p |
|---|---|---|---|---|---|
| **DA** | | | | | |
| Test Group Classification | 1 | 14.86 | 100% | .06 | <.0001* |

| | Measure | Canononical Coefficient | Within-Group Correlation |
|---|---|---|---|
| | DISTANCE | -.30 | .14 |
| | FUEL | .28 | .22 |
| | VELMEAN | -.05 | -.25 |
| | VELMOVE | .23 | -.04 |
| | HITRANGE | -.19 | .03 |
| | VBS | | .17 |
| | MAP | | .58 |

*All but one case successfully classified by group.

| Analyses | Measure | Cochran's C Value | Cochran's C p | Bartlett-Box F Value | Bartlett-Box F p |
|---|---|---|---|---|---|
| **Univariate Homogeneity of Variance Tests** | DISTANCE | .92 | <.001* | 25.81 | <.001* |
| | FUEL | .93 | <.001* | 28.92 | <.001* |
| | VELMEAN | .56 | .584 | .30 | .584 |
| | VELMOVE | .66 | .128 | 2.32 | .128 |
| | HITRANGE | .75 | .014* | 6.03 | .014* |
| | VBS | .53 | .817 | .05 | .817 |
| | MAP | .77 | .007* | 7.24 | .007* |

*statistically significant ($p<.05$)

Table 12

Offensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **React to a change of mission or fragmentary order (FRAGO)** | | | |
| Number of FRAGOs | M | 2 of 2 | 1.3 of 2 |
| successfully executed of 2 | SD | 0 | 0.5 |
| Time to plan FRAGOs | M | 6min | 15min |
| in minutes | SD | 2min | 3min |
| Time to execute FRAGOs | M | 24min | 33min |
| in minutes | SD | 5min | 12min |
| offFRAGO | M | 21 of 24 | 13 of 24 |
| criterion composite points | SD | 2 | 6 |
| ZoffFRAGO | M | +1.97 | -1.97 |
| normative composite z score | SD | 0.67 | 2.13 |
| **Report own location and control measures** | | | |
| Accuracy of grid | M | 4m | 396m |
| reported in meters | SD | 0.5m | 202m |
| Time to report | M | 11sec | 30sec |
| location in seconds | SD | 5sec | 20sec |
| offOWNREP | M | 79 of 80 | 65 of 80 |
| criterion composite points | SD | 1 | 4 |
| ZoffOWNREP | M | +1.36 | -1.36 |
| normative composite z score | SD | 0.29 | 1.03 |
| **Report enemy contact (CONTACT reports)** | | | |
| Number of reports sent | M | 9 of 10 | 7 of 10 |
| | SD | 1 | 3 |

Table 12 (Continued)

Offensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | Test Condition: IVIS | Test Condition: NO IVIS |
|---|---|---|---|
| **Report battlefield activity (CFF and SPOT reports)** | | | |
| Accuracy of grid | M | 203m | 497m |
| reported in meters | SD | 134m | 141m |
| Time to report | M | 114sec | 95sec |
| activity in seconds | SD | 47sec | 38sec |
| Number of report sent | M | 9 of 10 | 9 of 10 |
| | SD | 1 | 1 |
| offSPOTREP | M | 48 of 80 | 43 of 80 |
| criterion composite points | SD | 14 | 9 |
| ZoffSPOTREP | M | +0.20 | -0.20 |
| normative composite z score | SD | 2.74 | 1.08 |
| **Report indirect fire activity (SHELL reports)** | | | |
| Accuracy of grid | M | 419m | 653m |
| reported in meters | SD | 157m | 176m |
| Time to report | M | 42sec | 65sec |
| activity in seconds | SD | 11sec | 36sec |
| Number of reports sent | M | 10 of 10 | 9 of 10 |
| | SD | 1 | 2 |
| offSHELLREP | M | 55 of 80 | 42 of 80 |
| criterion composite points | SD | 7 | 9 |
| ZoffSHELLREP | M | +1.31 | -1.31 |
| normative composite z score | SD | 0.93 | 2.25 |

Table 12 (Continued)

Offensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Execute mission** | | | |
| Number of mission segments completed (offDONE) | M | 10 of 10 | 8 of 10 |
| | SD | 0 | 2 |
| Time to execute mission segments in minutes (offTIME) | M | 11min | 19min |
| | SD | 2min | 4min |
| Distance travelled in kilometers per mission segment completed | M | 2.5kms | 2.9kms |
| | SD | 0.2kms | 0.5kms |
| Fuel used in gallons per mission segment completed | M | 15gal | 23gal |
| | SD | 2gal | 8gal |
| Velocity in kilometers/hour (Overall) | M | 14kms/hr | 11kms/hr |
| | SD | 3kms/hr | 2kms/hr |
| Velocity in kilometers/hour (While Moving) | M | 29kms/hr | 29kms/hr |
| | SD | 6kms/hr | 5kms/hr |
| Percent of time within section dispersion above 200 meters | M | 38% | 15% |
| | SD | 23% | 9% |
| Percent of time within section dispersion above 500 meters | M | 11% | 8% |
| | SD | 10% | 5% |
| Percent of time between section dispersion above 500 meters | M | 26% | 25% |
| | SD | 15% | 20% |
| Range of target engagements in meters | M | 637m | 651m |
| | SD | 84m | 192m |
| Percent of time used vision blocks | M | 38% | 58% |
| | SD | 8% | 5% |
| Percent of time used paper map | M | 10% | 42% |
| | SD | 5% | 5% |
| Percent of time used IVIS | M | 52% | n/a |
| | SD | 7% | |

Table 12 (Continued)

Offensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Global reporting measure** | | | |
| offOTHERREP | M | +0.62 | -0.62 |
| criterion composite z score | SD | 0.82 | 0.78 |
| (contact, spot, shell, and CFF reports) | | | |
| ZoffOTHERREP | M | +2.00 | -2.00 |
| normative composite z score | SD | 3.33 | 2.46 |
| (contact, spot, shell, and CFF reports) | | | |

Note. Individual *t*-tests for each measure supported significant differences ($p<.05$) on all but 15 measures: (a) FRAGO execution time; (b) own location report time; (c) number of contact reports sent; (d) spot report time; (e) spot report criterion composite; (f) spot report normative composite; (g) shell report time; (h) number of shell reports sent; (i) distance travelled; (j) fuel used; (k) velocity overall; (l) velocity while moving; (m) within section dispersion; (n) across section dispersion, and (o) target engagement range.

Table 13

Defensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | Test Condition: IVIS | Test Condition: NO IVIS |
|---|---|---|---|
| **React to a change of mission or fragmentary order (FRAGO)** | | | |
| Number of FRAGOs successfully executed of 2 | M | 2.8 of 3 | 1.8 of 3 |
| | SD | 0.4 | 0.8 |
| Time to plan FRAGOs in minutes | M | 6min | 13min |
| | SD | 1min | 4min |
| Time to execute FRAGOs in minutes | M | 20min | 24min |
| | SD | 8min | 6min |
| defFRAGO criterion composite points | M | 21 of 24 | 11 of 24 |
| | SD | 5 | 7 |
| ZdefFRAGO normative composite z score | M | +1.58 | -1.58 |
| | SD | 1.90 | 1.91 |
| **Report own location and control measures** | | | |
| Accuracy of grid reported in meters | M | 10m | 317m |
| | SD | 16m | 136m |
| Time to report location in seconds | M | 9sec | 30sec |
| | SD | 3sec | 10sec |
| defOWNREP criterion composite points | M | 80 of 80 | 66 of 80 |
| | SD | 0 | 4 |
| ZdefOWNREP normative composite z score | M | +1.64 | -1.64 |
| | SD | 0.26 | 0.92 |
| **Report enemy contact (CONTACT reports)** | | | |
| Number of reports sent | M | 9 of 10 | 5 of 10 |
| | SD | 1 | 3 |

Table 13 (Continued)

Defensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | Test Condition: IVIS | Test Condition: NO IVIS |
|---|---|---|---|
| **Report battlefield activity (CFF and SPOT reports)** | | | |
| Accuracy of grid | M | 343m | 659m |
| reported in meters | SD | 153m | 257m |
| Time to report | M | 63sec | 102sec |
| activity in seconds | SD | 20sec | 49sec |
| Number of reports sent | M | 9 of 10 | 9 of 10 |
| | SD | 1 | 2 |
| defSPOTREP | M | 51 of 80 | 39 of 80 |
| criterion composite points | SD | 13 | 11 |
| ZdefSPOTREP | M | +0.66 | -0.66 |
| normative composite z score | SD | 1.96 | 1.91 |
| **Report indirect fire activity (SHELL reports)** | | | |
| Accuracy of grid | M | 361m | 829m |
| reported in meters | SD | 253m | 159m |
| Time to report | M | 34sec | 105sec |
| activity in seconds | SD | 7sec | 117sec |
| Number of reports sent | M | 10 of 10 | 7 of 10 |
| | SD | 1 | 2 |
| defSHELLREP | M | 62 of 80 | 32 of 80 |
| criterion composite points | SD | 11 | 9 |
| ZdefSHELLREP | M | +1.87 | -1.87 |
| normative composite z score | SD | 1.05 | 1.71 |

Table 13 (Continued)

Defensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Execute mission** | | | |
| Number of mission segments completed (defDONE) | M | 9.8 of 10 | 7.3 of 10 |
| | SD | 0.4 | 2.0 |
| Time to execute segments in minutes (defTIME) | M | 14min | 22min |
| | SD | 2min | 7min |
| Distance travelled in kilometers per segment completed | M | 2.8kms | 3.7kms |
| | SD | 0.3kms | 1.6kms |
| Fuel used in gallons per segment completed | M | 18gal | 27gal |
| | SD | 3gal | 10gal |
| Velocity in kilometers/hour (Overall) | M | 13kms/hr | 11kms/hr |
| | SD | 2kms/hr | 2kms/hr |
| Velocity in kilometers/hour (While Moving) | M | 28kms/hr | 26kms/hr |
| | SD | 3kms/hr | 4kms/hr |
| Percent of time within section dispersion above 200 meters | M | 33% | 18% |
| | SD | 18% | 5% |
| Percent of time within section dispersion above 500 meters | M | 5% | 6% |
| | SD | 5% | 12% |
| Percent of time between section dispersion above 500 meters | M | 12% | 5% |
| | SD | 6% | 5% |
| Range of target engagements in meters | M | 1,415m | 1,623m |
| | SD | 299m | 378m |
| Percent of time used vision blocks | M | 38% | 60% |
| | SD | 6% | 6% |
| Percent of time used paper map | M | 9% | 40% |
| | SD | 4% | 6% |
| Percent of time used IVIS | M | 53% | n/a |
| | SD | 5% | |

Table 13 (Continued)

Defensive Platoon Combat Mission Performance Measures by Test Condition: Means (M) and Standard Deviations (SD)

| Construct/Measures | | -----Test Condition----- IVIS | NO IVIS |
|---|---|---|---|
| **Global reporting measure** | | | |
| defOTHERREP | M | +0.81 | -0.81 |
| criterion composite z score (contact, spot, shell, and CFF reports) | SD | 0.59 | 0.53 |
| ZdefOTHERREP | M | +3.22 | -3.22 |
| normative composite z score (contact, spot, shell, and CFF reports) | SD | 2.78 | 2.27 |

Note. Individual *t*-tests for each measure supported significant differences (*p*<.05) on all but 14 measures: (a) FRAGO execution time, (b) FRAGO plan time, (c) spot report time, (d) number of spot reports sent, (e) spot report criterion composite, (f) spot report normative composite, (g) shell report time, (h) distance travelled, (i) fuel used, (j) velocity overall, (k) velocity while moving, (l) within section dispersion, (m) across section dispersion, and (n) target engagement range.

## Process Measure Analyses

A final set of MANOVA, *t*-test, DA, and homogeneity of variance analyses was conducted to evaluate group differences on seven miscellaneous measures collected. These measures reflected MANOVA analyses to limit the variable-to-sample size ratio. The results of these analyses are shown in Table 14.

Overall, the results indicated a significant IVIS versus NO IVIS platoon performance difference (i.e., a group main effect), but no differences across groups in platoon performance on the offensive and defensive missions (i.e., no mission main effect). A group by mission interaction was also not supported. Hence, IVIS and NO IVIS platoon performance difference were not contingent on the type of mission--offensive or defensive. Follow-up *t*-tests for the significant group main effect showed that, on the average, the IVIS-equipped platoons performed significantly better than the platoons without IVIS on each of the five composite measures evaluated.

Table 14

Offensive and Defensive Platoon Combat Missions: Repeated Measures MANOVA and *t*-tests for Criterion-Oriented Measures

| Analyses | Findings | | | |
|---|---|---|---|---|
| **MANOVA** Test Group Main Effect | Test Name | Value | Approx. F | Sig. of F |
| | Pillais | 0.99 | 136.20 | <.001* |
| | Hotellings | 113.50 | 136.20 | <.001* |
| | Wilks | 0.01 | 136.20 | <.001* |
| **MANOVA** Mission Main Effect | Test Name | Value | Approx. F | Sig. of F |
| | Pillais | 0.67 | 2.49 | .149 |
| | Hotellings | 2.07 | 2.49 | .149 |
| | Wilks | 0.33 | 2.49 | .149 |
| **MANOVA** Group by Mission Interaction | Test Name | Value | Approx. F | Sig. of F |
| | Pillais | 0.60 | 1.78 | .250 |
| | Hotellings | 1.49 | 1.78 | .250 |
| | Wilks | 0.40 | 1.78 | .250 |
| ***t*-tests** Test Group Mean Differences | Measure | t Value | Sig. of t | |
| | DONE | -3.06 | .012* | |
| | TIME | 3.45 | .006* | |
| | OWNREP | -23.59 | <.001* | |
| | OTHERREP | -4.30 | .002* | |
| | FRAGO | -3.29 | .012* | |

*Note*. DONE is the mean of offDONE and defDONE. TIME is the mean of offTIME and defTIME. OWNREP is the mean of offOWNREP and defOWNREP. OTHERREP is the mean of offOTHERREP and defOTHERREP. FRAGO is the mean of offFRAGO and defFRAGO.
*statistically significant ($p<.05$)

## Normative-Oriented Measure Analyses

A separate set of analyses, a partial repeated measures MANOVA and follow-up *t*-tests, were performed to evaluate group and mission differences on the normative-oriented composite measures (i.e., ZOWNREP, ZOTHERREP, and ZFRAGO) and the mission execution and percent of mission completed measures (TIME and DONE, respectively). The results of these analyses are summarized in Table 15.

The results of these analyses were consistent with the criterion-oriented measure analyses. The repeated measures MANOVA detected only a significant group (IVIS versus NO IVIS) main effect. No differences were detected in platoon performance across groups on the offensive and defensive combat mission. A group by mission interaction effect was also not supported. Hence, IVIS and NO IVIS group differences were consistent across both missions.

The *t*-test findings showed that IVIS-equipped platoons outperformed the platoons without IVIS on each of the five measures evaluated. Hence, across both the offensive and defensive missions, using either criterion or normative-oriented measures, the platoons who used IVIS completed a greater percentage of each mission in less time, with better own-location and battlefield reporting, and superior FRAGO performance.

## Process Measure Analyses

Finally, a series of *t*-tests was performed to evaluate IVIS versus NO IVIS platoon performance differences across both missions on 10 miscellaneous measures collected. These measures reflected behaviors or outcomes that were not necessarily related to superior platoon tactical performance, including fuel use, distance travelled, engagement range, velocity, unit dispersion, and vision block and paper map use indices. These analyses are summarized in Table 16.

Overall, significant group differences were supported for four of the 10 measures evaluated: fuel use, mean velocity, vision block use, and paper map use ratings. On the average, the IVIS-equipped platoon commanders, like the crew commanders in the small unit $C^3$ exercise, spent a smaller percentage of time looking out their tanks' vision blocks and sights and using their paper map than the NO IVIS platoons. Moreover, the commanders with IVIS used less fuel and maintained a higher average velocity in completing the missions. No significant group differences were detected on the unit dispersion, moving velocity, engagement range, and distance travelled measures.

Table 15

Offensive and Defensive Platoon Combat Missions: Repeated Measures MANOVA and t-tests for Normative-Oriented Measures

| Analyses | Findings | | | |
|---|---|---|---|---|
| **MANOVA** | Test Name | Value | Approx. F | Sig. of F |
| Test Group | Pillais | 0.99 | 118.75 | <.001* |
| Main Effect | Hotellings | 98.96 | 118.75 | <.001* |
| | Wilks | 0.01 | 118.75 | <.001* |
| **MANOVA** | Test Name | Value | Approx. F | Sig. of F |
| Mission | Pillais | 0.69 | 2.69 | .130 |
| Main Effect | Hotellings | 2.24 | 2.69 | .130 |
| | Wilks | 0.31 | 2.69 | .130 |
| **MANOVA** | Test Name | Value | Approx. F | Sig. of F |
| Group by | Pillais | 0.44 | 0.93 | .520 |
| Mission | Hotellings | 0.78 | 0.93 | .520 |
| Interaction | Wilks | 0.56 | 0.93 | .520 |
| **t-tests** | Measure | t Value | Sig. of t | |
| Test Group Mean | DONE | -3.06 | .012* | |
| Differences | TIME | 3.45 | .006* | |
| | ZOWNREP | -12.01 | <.001* | |
| | ZOTHERREP | -3.87 | .003* | |
| | ZFRAGO | -3.84 | .003* | |

Note. DONE is the mean of offDONE and defDONE. ZTIME is the mean of offTIME and defTIME. ZOWNREP is the mean of ZoffOWNREP and ZdefOWNREP. ZOTHERREP is the mean of ZoffOTHERREP and ZdefOTHERREP. ZFRAGO is the mean of ZoffFRAGO and ZdefFRAGO. *statistically significant ($p<.05$)

## IVIS Usage Measures

Table 17 presents the means and standard deviations by mission (offensive and defensive) for each of the four IVIS usage measures collected. These measures included the number of reports sent, the number of reports in the queue, the percent of reports called up from the queue, and the time to call reports from the queue.

Throughout the offensive and defensive missions, the commanders in the platoon sent an average of 290 and 332 reports, respectively. More than 90 percent of these reports were

Table 16

Platoon Combat Missions: *t*-tests for Additional Measures

| Measure | *t*-value | Sig of *t* |
|---|---|---|
| Distance travelled per mission segment completed in kilometers | 1.60 | .141 |
| Fuel used per mission segment completed in gallons | 2.37 | .039* |
| Engagement range in meters | 1.06 | .312 |
| Velocity in kilometers/hour (Overall) | -2.34 | .042* |
| Velocity in kilometers/hour (While Moving) | -0.53 | .609 |
| Percent of time within section dispersion above 200 meters | -2.03 | .069 |
| Percent of time within section dispersion above 200 meters | -0.35 | .733 |
| Percent of time between section dispersion above 500 meters | -0.70 | .501 |
| Percent of time used vision blocks | 6.36 | <.001* |
| Percent of time used paper map | 12.51 | <.001* |

*Note*. All but the unit dispersion measures are averaged across all four commanders in the platoon.
*statistically significant ($p<.05$)

battlefield reports, including contact, spot, shell, CFF, and CFF adjustment reports. In fact, on the average, the commanders sent more than 9 reports for each of the 30 battlefield combat events (i.e., target engagements, artillery impacts). Furthermore, across the two and one-half hours allotted for exercise completion, at least one commander sent an IVIS report, on the average, every 30 seconds.

Despite the number of reports sent, the platoon leaders were able to almost always maintain an empty queue, with an average queue size of 0.5 and 0.3 across the offensive and defensive missions, respectively. Tank commanders, however, maintained, on the average, more than four reports in their queue throughout each mission. At their fullest points across each mission, the platoon leaders' queues included about four reports, while the tank commanders' queues reached a peak of more than 13 reports.

Across both missions, the platoon leaders read over 94 percent of the reports they received over IVIS, while the tank commanders read only about 75 percent of the reports they received. Despite the "Message Waiting" alerts and audible cues presented when reports entered a commander's IVIS queue, the commanders, on the average, took considerable time in calling up both battlefield and logistics reports. For example, across the offensive mission the commanders took, on the average, three minutes to call up battlefield reports and five minutes to call up logistics reports. During the defensive mission, commanders called up battlefield and logistics reports from the queue about four and two minutes after their receipt, respectively.

Across the offensive mission, the commanders did call up higher priority reports (e.g., calls for fire, contact reports) more rapidly than lower priority reports (e.g., ammunition status and situation reports). On the average, both platoon leaders and tank commanders responded to priority one reports in about half the time they required to call up priority three reports. Nevertheless, while platoon leaders responded similarly to higher priority reports in the defensive mission, the tank commanders took nearly seven minutes to call up reports, regardless of their priority.

## IVIS Training Evaluation Measures

The IVIS Knowledge Test, IVIS Performance Test, and IVIS Training Reactions Questionnaire provided numerous measures for evaluating the effectiveness of the experimental IVIS training program used in the current research. The described analyses of these measures follow.

Table 17

Offensive and Defensive Platoon Combat Missions: Means (M) and Standard Deviations (SD) for IVIS Usage Measures for Platoon Leaders and Tank Commanders

| Measure | | Offensive M | Offensive SD | Defensive M | Defensive SD |
|---|---|---|---|---|---|
| **Number of reports sent** | | | | | |
| Battlefield Reports* | | 270 | 80 | 310 | 94 |
| Logistics Reports** | | 20 | 14 | 22 | 13 |
| **Number of reports in queue** | | | | | |
| Mean Reports in Queue | PL | 0.5 | 0.5 | 0.3 | 0.2 |
| | TC | 4.2 | 4.4 | 4.4 | 4.0 |
| Max Report in Queue | PL | 3.5 | 1.9 | 3.5 | 1.1 |
| | TC | 13.4 | 8.7 | 15.7 | 12.6 |
| **Percent of reports called up from queue** | | | | | |
| | PL | 94% | 8% | 98% | 3% |
| | TC | 76% | 20% | 77% | 25% |
| **Time to call up reports from queue** | | | | | |
| Battlefield Reports | | 3min | 3min | 4min | 4min |
| Logistics Reports | | 5min | 3min | 2min | 2min |
| Priority 1 Reports | PL | 1min | 1min | 1min | 1min |
| | TC | 7min | 6min | 7min | 7min |
| Priority 2 Reports | PL | 2min | 2min | 2min | 1min |
| | TC | 11min | 10min | 7min | 7min |
| Priority 3 Reports | PL | 2min | 4min | 3min | 4min |
| | TC | 15min | 13min | 6min | 9min |

*includes contact, spot, shell, CFF, and CFF adjust reports
**includes situation and ammo status reports

## IVIS Knowledge Test Analyses

On the average, the 24 IVIS-equipped commanders correctly answered 83 percent or 33 of the 40 IVIS Knowledge Test items (i.e., mean of 32.83, standard deviation of 3.24). By chance, commanders could be expected to correctly respond to only 25% or 10 of the 40 multiple choice items. Only seven items, item 9 (own location window), 15 (line of sight), 26 (map zoom), 29 (IVIS report keys), 38 (CFF adjust), 39 (relay report), and 40 (show report), were not correctly answered by at least 75% of the commanders. The percentage of commanders who correctly responded to each test item is presented in Table 18.

Reliability analyses supported moderate reliability for the IVIS Knowledge Test score, with coefficient alpha, split-half, and Kuder-Richardson reliability coefficients of .60, .62, .58, respectively. Five items were correctly answered by every commander, including items 4 (report priority), 10 (route designation), 18 (shell report), 19 (CFF adjust), and 22 (route designation). In addition, ten items were missed by less than 10% of the commanders. Hence, these coefficients were attenuated.

## IVIS Performance Test Analyses

The IVIS Performance Test provided a means to evaluate, both immediately after the completion of training and following the execution of the crew and platoon exercises, the IVIS proficiency of the 24 commanders in the IVIS treatment condition. Table 19 presents the 28 IVIS function proficiency rating means and standard deviations for each test administration. The tasks are ranked, using post-training ratings, from those in which commanders demonstrated most to least proficiency. No significant differences were detected within each administration between the test administrator and commander proficiency ratings. Hence, only the more reliable, composite average of these ratings is provided for each function.

Overall, on the average, for all but two **MAP** Symbols tasks on the first (post-training) proficiency assessment and for all tasks on the second (post-exercises) assessment, the commanders demonstrated "moderate" (4) or higher IVIS proficiency. Across all 28 tasks, the commanders demonstrated an overall IVIS proficiency rating of "high" (mean was 5.17, standard deviation was 0.53) for the post-training proficiency assessment.

Following the completion of the crew and platoon exercises, the commanders' overall IVIS proficiency improved one rating point to "very high" (mean was 6.06, standard deviation was 0.56). This proficiency improvement was statistically significant ($t$=-7.20, $p$<.001).

Table 18

IVIS Knowledge Test: Percent of Commanders Correctly Answering Each Item

| Content | Item | Percent Correct | Content | Item | Percent Correct |
|---|---|---|---|---|---|
| **REP** Priority | 4 | 100% | **NAV** Driver | 35 | 88% |
| **NAV** Route | 10 | 100% | **MAP** Overlay | 2 | 83% |
| **REP** Shell | 18 | 100% | **REP** Adjust | 24 | 83% |
| **CFF** Adjust | 19 | 100% | **SCROLL** Vel | 30 | 83% |
| **NAV** Driver | 22 | 100% | **MAP** Sym/Lab | 33 | 83% |
| Map Display | 3 | 96% | Map Display | 34 | 83% |
| **REP** Priority | 5 | 96% | Own Window | 11 | 79% |
| **SCROLL** Lock | 6 | 96% | **MAP** LOS | 14 | 79% |
| Own Window | 7 | 96% | **REP** Contact | 28 | 79% |
| **REP** Spot | 16 | 96% | Own Window | 1 | 75% |
| **REP** Spot | 17 | 96% | **MAP** Spot | 25 | 75% |
| **MAP** | 12 | 92% | **SCROLL** | 31 | 75% |
| **SCROLL** Home | 21 | 92% | **CON** Auto | 37 | 75% |
| **REP** SitRep | 27 | 92% | **MAP** Zoom | 26 | 71% |
| **MAP** Symbols | 36 | 92% | **RECEIVE** Show | 40 | 71% |
| IVIS Acronym | 8 | 88% | **REP** | 29 | 67% |
| **SCROLL** | 13 | 88% | Own Window | 9 | 59% |
| **SEND** | 20 | 88% | **MAP** LOS | 15 | 33% |
| **REP** Spot | 23 | 88% | **RECEIVE** ACT | 39 | 33% |
| **REP** Contact | 32 | 88% | **REP** Adjust | 38 | 13% |

Table 19

IVIS Performance Test: Item Means (M), Standard Deviations (SD), and Commander Proficiency Rankings (Rank) for Post-Training and Post-Exercises Administrations

| Function | Item | Post-Training M | SD | Rank | Post-Exercises M | SD | Rank |
|---|---|---|---|---|---|---|---|
| **MAP** Symbols | 16 | 2.98 | 1.79 | 1 | 4.52 | 1.86 | 1 |
| **MAP** Symbols | 14 | 3.96 | 1.71 | 2 | 5.52 | 1.14 | 3 |
| **MAP** Spots | 13 | 4.23 | 2.06 | 3 | 5.56 | 1.63 | 4 |
| **RECEIVE** ACT | 26 | 4.25 | 1.82 | 4 | 5.56 | 1.30 | 4 |
| **MAP** Spots | 15 | 4.38 | 2.02 | 5 | 5.98 | 1.63 | 11 |
| **MAP** Terrain | 6 | 4.40 | 1.48 | 6 | 5.67 | .78 | 6 |
| **RECEIVE** SHOW | 28 | 4.79 | 1.85 | 7 | 5.75 | 1.48 | 8 |
| **MAP** Labels | 12 | 4.81 | 1.47 | 8 | 6.04 | .92 | 12 |
| **SCROLL** LOCK | 23 | 4.83 | 1.28 | 9 | 5.71 | 1.17 | 7 |
| **REP** Ammo | 17 | 4.85 | 1.76 | 10 | 6.21 | .93 | 14 |
| **REP** SitRep | 19 | 5.02 | 1.06 | 11 | 5.48 | .98 | 2 |
| **MAP** LOS | 8 | 5.02 | 1.33 | 11 | 6.21 | .81 | 14 |
| **MAP** LOS | 9 | 5.10 | 1.94 | 13 | 6.29 | 1.08 | 19 |
| **CFF** Adjust | 5 | 5.17 | .89 | 14 | 5.96 | .81 | 9 |
| **CON** Rep | 3 | 5.27 | .92 | 15 | 6.27 | .72 | 18 |
| **CFF** Rep | 4 | 5.35 | .65 | 16 | 6.23 | .55 | 16 |
| **MAP** Zoom | 18 | 5.42 | 1.37 | 17 | 6.38 | .70 | 21 |
| **MAP** Symbols | 11 | 5.54 | .91 | 18 | 6.25 | .71 | 17 |
| **REP** Shell | 10 | 5.56 | 1.06 | 19 | 6.40 | .55 | 22 |
| **REP** Spot | 7 | 5.58 | .79 | 20 | 5.96 | .67 | 9 |
| **RECEIVE** | 25 | 5.71 | 1.32 | 21 | 6.40 | .88 | 22 |
| **MAP** Overlay | 27 | 5.79 | 1.55 | 22 | 6.33 | 1.26 | 20 |
| **NAV** Route | 20 | 5.83 | .94 | 23 | 6.40 | .51 | 22 |
| **REP** Shell | 22 | 5.85 | .89 | 24 | 6.19 | .79 | 13 |
| **REP** Contact | 2 | 5.98 | .63 | 25 | 6.58 | .49 | 25 |
| Loc Window | 1 | 6.25 | 1.23 | 26 | 6.58 | .48 | 25 |
| **SCROLL** Home | 24 | 6.40 | 1.22 | 27 | 6.58 | .50 | 25 |
| **NAV** Driver | 21 | 6.44 | .85 | 28 | 6.79 | .39 | 28 |

Note. Ratings were based on seven-point proficiency scale, with anchors ranging from not at all proficient (1) to expert (7). RANK represents the degree to which commanders, on the average, demonstrated proficiency with the function/task. Functions are listed from those in which commanders demonstrated least to most proficiency, based on post-training rating means. Post-training ratings were gathered immediately after the completion of the experimental IVIS training program. Post-exercises ratings were collected after the completion of the SIMNET-D exercises.

Performance improvement appears consistent across the post-training and post-exercises assessments. Task rating means improved about one rating point for each task on the second, post-exercises, IVIS proficiency assessment. Moreover, the rank order of the 28 tasks, based on the degree to which the commanders' demonstrated proficiency, was consistent across both administrations. These rankings correlated .86 ($\underline{p}$<.001).

Table 20 shows the percentage of commanders who demonstrated "acceptable" proficiency by IVIS task for each test administration. Acceptable proficiency, for the purpose of the current research, was indicated by a mean task proficiency rating of five ("moderate") or higher. These data showed that for the post-training assessment, 75 percent or more of the commanders demonstrated acceptable proficiency for only 13 of the 28 tasks. Nevertheless, at least half of the commanders demonstrated acceptable proficiency on all but three tasks: 14 (**MAP** Symbols-Delete), 16 (**MAP** Symbols-Create Lines), and 26 (**RECEIVE** ACT). The commanders also had difficulty performing the **MAP** LABELS, **MAP** LOS, **MAP** SPOTS, **REP** SITREP, and **REP** AMMO functions.

A greater percentage of commanders achieved acceptable proficiency levels on the second, post-exercises assessment. At least 90% of the commanders demonstrated acceptable IVIS task proficiency for 20 of the 28 tasks. At least half of the commanders demonstrated acceptable proficiency levels on all of the tasks. Again, however, **MAP** Symbols, and **RECEIVE** tasks were the most difficult for commanders to perform.

Split-half, coefficient alpha, and intraclass correlation reliability coefficients were all above .90 ($\underline{p}$<.001), supporting the high reliability of both the post-training and post-exercises IVIS Performance Test assessment data. The test-retest reliability coefficient was .63 ($\underline{p}$<.001) but was attenuated as a result of differential learning among the IVIS commanders. Interrater reliability coefficients were above .60 for both administrations, suggesting moderately high reliability.

## IVIS Training Reactions Questionnaire Analyses

Training Effectiveness and Training Time Ratings. Table 21 shows the overall training effectiveness and training time rating means and standard deviations for each of the 26 IVIS functions that were operational in the current research's IVIS prototype. On the average, the commanders indicated that the IVIS training program used in this research was "highly effective" for three functions (REP Log, SCROLL Vel, and CFF Adjust) and "quite effective" for the remaining 23 functions. Furthermore, all of the 26 tasks, on the average, were rated by the commanders as requiring "slightly more" training time in a revised and improved training program.

Table 20

IVIS Performance Test: Percent of Commanders Demonstrating Acceptable Proficiency by Task for the Post-Training and Post-Exercises Administrations

| IVIS Function | Item | Post-Training Percent Can M | Post-Training Percent Can SD | Post-Exercises Percent Can M | Post-Exercises Percent Can SD |
|---|---|---|---|---|---|
| **MAP** Symbols | 16 | 21% | 41% | 58% | 50% |
| **MAP** Symbols | 14 | 38% | 49% | 79% | 41% |
| **RECEIVE** ACT | 26 | 42% | 50% | 75% | 44% |
| **MAP** Terrain | 6 | 50% | 51% | 92% | 28% |
| **MAP** LOS | 8 | 50% | 51% | 96% | 20% |
| **MAP** Spots | 13 | 50% | 51% | 83% | 38% |
| **MAP** Labels | 12 | 54% | 51% | 92% | 28% |
| **MAP** Spots | 15 | 54% | 51% | 87% | 34% |
| **REP** Ammo | 17 | 58% | 50% | 92% | 28% |
| **REP** SitRep | 19 | 58% | 50% | 79% | 41% |
| **MAP** LOS | 9 | 63% | 49% | 92% | 28% |
| **SCROLL** Lock | 23 | 63% | 49% | 79% | 41% |
| **CFF** Adjust | 5 | 67% | 48% | 92% | 28% |
| **MAP** Zoom | 18 | 67% | 48% | 100% | 0% |
| **RECEIVE** Show | 28 | 67% | 48% | 79% | 41% |
| **CON** Rep | 3 | 75% | 44% | 96% | 20% |
| **RECEIVE** | 25 | 79% | 41% | 96% | 20% |
| **MAP** Overlay | 27 | 79% | 41% | 92% | 28% |
| **REP** Spot | 7 | 83% | 38% | 96% | 20% |
| **REP** Shell | 10 | 83% | 38% | 100% | 0% |
| **MAP** Symbols | 11 | 87% | 34% | 96% | 20% |
| **NAV** Route | 20 | 87% | 34% | 100% | 0% |
| Loc Window | 1 | 92% | 28% | 100% | 0% |
| **REP** Contact | 2 | 92% | 28% | 100% | 0% |
| **CFF** Rep | 4 | 92% | 28% | 100% | 0% |
| **REP** Shell | 22 | 92% | 28% | 92% | 28% |
| **SCROLL** Home | 24 | 92% | 28% | 100% | 0% |
| **NAV** Driver | 21 | 96% | 20% | 100% | 0% |

Note. Ratings were based on seven-point proficiency scale, with anchors ranging from not at all proficient (1) to expert (7). Percent Can is percent of commanders achieving at least a rating of five, "moderate proficiency," for the task.

Table 21

IVIS Training Reactions Questionnaire: Overall Means (M) and Standard Deviations (SD) for Training Effectiveness and Training Time Ratings by IVIS Function

| IVIS Function | Item | Effectiveness M | Effectiveness SD | Time Needed M | Time Needed SD |
|---|---|---|---|---|---|
| **NAV** Route | 18 | 1.67 | 1.44 | 3.17 | 1.09 |
| **MAP** Zoom | 10 | 1.75 | 1.11 | 3.38 | 1.17 |
| **SCROLL** Home | 19 | 1.75 | 1.62 | 3.29 | 1.16 |
| **REP** Contact | 11 | 1.79 | 1.47 | 3.00 | 1.29 |
| **RECEIVE** | 23 | 1.83 | 1.01 | 2.96 | 1.08 |
| **MAP** Features | 4 | 1.88 | 1.26 | 2.92 | 1.10 |
| **SEND** | 26 | 1.96 | 1.30 | 2.96 | 1.04 |
| **MAP** Overlay | 6 | 2.00 | 1.32 | 3.38 | 1.10 |
| **REP** Shell | 15 | 2.00 | 1.29 | 3.13 | 1.15 |
| **REP** Spot | 13 | 2.08 | 1.38 | 3.04 | 1.04 |
| **SCROLL** Drag | 21 | 2.08 | 1.44 | 3.04 | 1.12 |
| **MAP** Symbols | 8 | 2.13 | 1.30 | 3.13 | 0.99 |
| **SCROLL** Lock | 22 | 2.13 | 1.54 | 3.38 | 1.06 |
| **MAP** Spots | 7 | 2.17 | 1.24 | 2.92 | 1.14 |
| **CON** | 1 | 2.21 | 1.14 | 3.04 | 1.12 |
| **MAP** Labels | 9 | 2.21 | 1.38 | 3.21 | 1.06 |
| **MAP** LOS | 5 | 2.25 | 1.48 | 3.21 | 1.14 |
| **CON** Auto | 2 | 2.29 | 1.26 | 3.04 | 1.20 |
| **REP** SitRep | 14 | 2.29 | 1.37 | 2.92 | 1.06 |
| **RECEIVE** ACT | 25 | 2.29 | 1.16 | 2.83 | 1.13 |
| **CFF** | 3 | 2.33 | 1.55 | 2.83 | 1.20 |
| **REP** CFF | 12 | 2.46 | 1.69 | 2.67 | 1.13 |
| **REP** Adjust | 17 | 2.50 | 1.56 | 2.96 | 1.16 |
| **REP** Log | 16 | 2.58 | 1.69 | 3.13 | 1.04 |
| **SCROLL** Vel | 20 | 2.63 | 1.56 | 2.75 | 1.15 |
| **RECEIVE** SHOW | 24 | 2.63 | 1.41 | 2.88 | 1.12 |

Note. Training effectiveness and training time ratings based on seven-point rating scales. For the training effectiveness scale, anchors ranged from extremely effective (1) to extremely ineffective (7). For the training time ratings, anchors ranged from extremely more time needed (1) to extremely less time needed (7). Ratings completed immediately after IVIS training. IVIS functions ranked from those for which training was most to least effective, based on mean commander ratings.

The training effectiveness and training time rating means and standard deviations, by training phase (classroom instruction, hands-on practice, crew practice exercise, and platoon practice mission), averaged across all 26 functions, are included in Table 22.

Overall, the IVIS-equipped commanders indicated that, on the average, the IVIS classroom instruction was at best only "slightly effective." Hence, the commanders indicated that no more time, and perhaps even less time, should be devoted to classroom instruction. The hands-on, crew exercise, and platoon mission training sessions were all rated as "quite effective." Nevertheless, the commanders indicated that "slightly more" time should be spent in hands-on, crew, and platoon practice sessions.

As with the IVIS Knowledge Test and IVIS Performance Test measures, the training effectiveness and time measures were at least moderately reliable, with coefficient alpha, split-half, and intraclass correlation coefficients above .90 ($p<.001$)

Other Ratings. In addition to the completion of training effectiveness and training time ratings, the 24 IVIS-equipped commanders also indicated their level of agreement with 16 statements about the IVIS training program. The means and standard deviations for each of these item ratings are included in Table 23.

On the average, the commanders agreed that the research assistants and classroom instructors knew IVIS well and that the training was well organized. Moreover, the commanders asserted, on the average, that IVIS training should include more unstructured or free-play practice time. The commanders also suggested that the IVIS Knowledge Test and SIMNET-D Knowledge Test covered material taught in training and that the IVIS Performance Test ratings accurately reflected their IVIS proficiency after training. The commanders were mixed, however, on the usefulness of the videotapes and handouts used during the classroom lecture.

Soldier Comments. Following IVIS training, the commanders completed nine partial statements about the IVIS training program and also offered additional verbal reactions to the training instructors and administrators. Overall, these comments were consistent with the previous training evaluation findings described above and indicated that the commanders were quite satisfied with the experimental IVIS training program, particularly the hands-on, crew, and platoon practice sessions.

The commanders were critical at times, however, about the classroom instruction. Many commanders believed that the lecture focused too much on verbal descriptions of IVIS functions and procedures. Instead, the commanders thought that the lecture

Table 22

IVIS Training Reactions Questionnaire: Overall Training Effectiveness and Training Time Rating Means (M) and Standard Deviations (SD) by Training Phase

| Training Phase | Effectiveness M | Effectiveness SD | Time Needed M | Time Needed SD |
|---|---|---|---|---|
| Classroom Instruction | 3.43 | 1.12 | 3.76 | 0.86 |
| Hands-On Practice | 1.98 | 1.15 | 3.04 | 0.88 |
| Crew Practice Exercise | 2.05 | 1.15 | 2.98 | 0.97 |
| Platoon Practice Exercise | 2.10 | 1.13 | 3.00 | 0.96 |
| Overall | 2.16 | 1.11 | 3.04 | 0.91 |

Note. Training effectiveness and training time ratings based on seven-point rating scales. For the training effectiveness scale, anchors ranged from extremely effective (1) to extremely ineffective (7). For the training time ratings, anchors ranged from extremely more time needed (1) to extremely less time needed (7). Ratings completed immediately after IVIS training.

Table 23

IVIS Training Reactions Questionnaire: Commander Rating Means (M) and Standard Deviations (SD) for Additional IVIS Training Issues

| Item | M | SD |
|---|---|---|
| 1. The classroom instructor seemed to know a lot about IVIS. | 4.04 | 1.00 |
| 2. The classroom instructor did not adequately explain how to use the IVIS functions. | 2.58 | 1.06 |
| 3. The training I received in the simulator by the research assistant was not well organized. | 1.63 | 1.21 |
| 4. The research assistant seemed to know a lot about IVIS. | 4.54 | 0.59 |
| 5. I didn't use some IVIS functions because I didn't understand them. | 2.54 | 1.32 |
| 6. My research assistant didn't show me how to use some IVIS functions. | 2.33 | 1.31 |
| 7. The SIMNET-D video tape contained important information. | 3.04 | 1.12 |
| 8. More unstructured time to practice using each of the IVIS functions would be helpful. | 4.08 | 1.06 |
| 9. The research assistants were helpful. | 4.75 | 0.44 |
| 10. The training program was disorganized. | 1.50 | 0.51 |
| 11. The IVIS handouts during the lecture were helpful. | 3.21 | 0.98 |
| 12. The visual aids used during the lecture were helpful. | 3.08 | 0.93 |
| 13. The lecture was well organized. | 3.92 | 0.72 |
| 14. The IVIS knowledge test covered material I was taught during training. | 4.13 | 0.61 |
| 15. The ratings of my IVIS proficiency after training are accurate. | 4.13 | 0.61 |
| 16. The SIMNET-D knowledge test covered material I was never taught during training. | 2.00 | 1.02 |

Note. Ratings based on five-point scale, with anchors ranging from strongly disagree (1) to strongly agree (5). Ratings collected immediately after training.

should have been supported with a static or preferably, dynamic, IVIS prototype and other visual aids. The hands-on, crew, and platoon practice sessions were consistently rated as excellent, although many commanders suggested that these sessions be longer. In addition, the commanders stressed the importance of also using IVIS in the field for training.

Finally, the commanders indicated the importance of frequent follow-up refresher training on both IVIS and conventional $C^3$ and other related task procedures. Without consistent conventional training, many commanders expressed concern that if IVIS broke down, they would be left in the very dangerous position of trying to remember and effectively perform conventional procedures.

## Task Difficulty Questionnaire Analyses

Table 24 presents the overall task difficulty rating means and standard deviations across the 24 IVIS and NO IVIS commanders. Data are presented for each of the three task difficulty assessment conditions, including: (a) the initial (pre-training) ratings of the difficulty of performing $C^3$ tasks in the field in a real tank using conventional tools and procedures (T1TANK); (b) a follow-up (post-exercises) assessment of the difficulty of performing $C^3$ tasks in the field; and (c) an assessment, following testing, of the difficulty of performing $C^3$ tasks in SIMNET-D in their particular IVIS or NO IVIS test condition (SIMNET-D). Split-half and coefficient alpha reliability coefficients for these means were all above .90 ($p<.001$).

On the average, the commanders in the IVIS condition rated $C^3$ task performance in SIMNET-D with IVIS as "quite easy". The NO IVIS commanders, however, rated the performance of the same $C^3$ tasks performed in SIMNET-D without IVIS as, at best, "slightly easy." The difference between the IVIS and NO IVIS commander SIMNET-D ratings is significant ($t$=5.66, $p$<.001).

Pre-training tank in the field task difficulty ratings were not significantly different between the IVIS and NO IVIS commanders ($t$=.943, $p$=.454). The commanders in each group initially rated the $C^3$ tasks, on the average, as somewhere between "slightly easy" and "neither easy nor difficult." After the completion of the crew and platoon exercises in SIMNET-D, however, the NO IVIS commanders' perceptions of the difficulty of $C^3$ task performance in the field changed. After testing, the NO IVIS commanders rated $C^3$ performance in the field, on the average, as easier than they had initially estimated ($t$=3.23, $p$=.004). There was no difference, however, between the pre-training and post-exercises tank in the field ratings for the IVIS-equipped commanders ($t$=-.120, $p$=.906).

Table 24

Task Difficulty Questionnaire: Overall Means (M) and Standard Deviations (SD) by Test Condition for Each Assessment Condition

| Measure | IVIS M | IVIS SD | NO IVIS M | NO IVIS SD |
|---|---|---|---|---|
| T1TANK | 3.81 | 1.14 | 3.56 | 0.90 |
| T2TANK | 3.83 | 1.10 | 2.97 | 1.10 |
| SIMNET-D | 1.89 | 0.60 | 3.32 | 1.04 |

* T1TANK is mean pre-training tank in the field $C^3$ task difficulty rating. T2TANK is post-exercises tank in the field $C^3$ task difficulty rating. SIMNET-D is mean post-exercises $C^3$ task difficulty rating for performance in SIMNET-D in each commander's IVIS or NO IVIS condition. Ratings based on seven-point scale, with anchors from extremely easy (1) to extremely difficult (7).

For the post-exercises ratings, the NO IVIS commanders rated the $C^3$ task performance in the field as significantly easier than $C^3$ performance in SIMNET-D without IVIS ($t$=-2.62, $p$=.017). There were no differences, however, between the pre-training tank in the field and SIMNET-D ratings ($t$=1.07, $p$=.298).

For the IVIS commanders, however, SIMNET-D-based $C^3$ task performance with IVIS was rated as significantly easier than $C^3$ task performance in the field using conventional procedures using both the pre-training tank ratings ($t$=8.84, $p$=<.001) and post-exercises ratings ($t$=7.83, $p$=<.001).

Difficulty rating means and standard deviations for each of the 28 $C^3$ tasks for each difficulty assessment are included, by test condition, in Appendix H.

## IVIS Interface Questionnaire Analyses

### IVIS Issue Ratings

As part of the IVIS Interface Questionnaire, the 24 IVIS-equipped commanders indicated their level of agreement with 69 statements about the IVIS system. Ratings were based on a five-point Likert rating scale, with anchors ranging from strongly disagree (1) to strongly agree (5). The means and standard deviations for each of the 69 rating items, as well as item response frequency distributions, are included in Appendix I.

On the average, the commanders expressed positive reactions to the IVIS interface. The commanders indicated consistent support for IVIS and agreed that IVIS improved their performance and should be included in the upgraded Block II M1 tank. The commanders also agreed that the location of IVIS in the M1 simulator (right and down from the commander's primary sight extension) was acceptable.

Similarly, the commanders indicated satisfaction with most of the IVIS report formats, the map overlay and features functions, the own-location update and map scroll rates, the procedures for entering, updating, and relaying IVIS route waypoints, the readability of the IVIS map display at 1:25,000 and 1:50,000 map scales, and the mutual POSNAV capabilities.

On the average, the commanders believed that the IVIS map was more useful than a paper map and that they sent more accurate and complete reports with IVIS than they could using conventional tools and procedures. However, the commanders agreed that they spent too much time reading IVIS reports. The commanders consistently indicated a preference for using IVIS, rather than a radio, for sending reports. The commanders believed they could react better to reports sent over IVIS.

The commanders suggested that the IVIS display was too small and expressed mixed reactions to the IVIS touch screen. Moreover, the commanders indicated mixed support for the visual and auditory cues and the decision rules used to prioritize IVIS reports. The commanders agreed that they spent more time looking at the IVIS display during the crew and platoon exercises than they tactically should have, but added that with experience, they were able to direct more attention away from IVIS and onto the battlefield. The commanders also expressed mixed reactions regarding the ability of IVIS to improve target acquisition.

IVIS Ease-of-Learning, Ease-of-Use, and Helpfulness Ratings

As part of the IVIS Interface Questionnaire, the 24 IVIS-equipped commanders also rated the degree to which each of the 26 IVIS functions evaluated were easy to learn, easy to use, and helpful. Each of these ratings were based on seven-point rating scales. Anchors ranged from extremely easy (1) to extremely difficult (7) for the ease-of-learning and ease-of-use ratings. For the helpfulness ratings, anchors ranged from extremely helpful (1) to extremely unhelpful (7). The ease-of-learning, ease-of-use, and helpfulness rating means and standard deviations for each of the 26 IVIS functions are included in Table 25.

Overall, each of the IVIS functions were rated, on the average, as "quite" easy to learn, easy to use, and helpful. Moreover, the commanders' reactions indicate little

Table 25

IVIS Interface Questionnaire: Commander Ease-of-Learning (LEARN), Ease-of-Use (USE), and Helpfulness (HELP) Rating Means (M) and Standard Deviations (SD)

| IVIS Function | LEARN M | LEARN SD | USE M | USE SD | HELP M | HELP SD |
|---|---|---|---|---|---|---|
| **CON** Rep | 1.96 | 0.91 | 1.79 | 0.83 | 1.67 | 0.76 |
| **CON** Auto | 2.33 | 1.24 | 1.92 | 0.93 | 1.88 | 1.04 |
| **CFF** Rep | 2.04 | 1.00 | 1.75 | 0.94 | 1.46 | 0.78 |
| **MAP** Features | 2.13 | 1.12 | 1.50 | 0.72 | 1.54 | 0.72 |
| **MAP** LOS | 2.38 | 1.28 | 1.79 | 1.02 | 2.25 | 1.26 |
| **MAP** Overlay | 2.25 | 1.29 | 1.54 | 0.66 | 1.42 | 0.65 |
| **MAP** Spots | 2.54 | 1.56 | 1.88 | 0.99 | 2.46 | 1.47 |
| **MAP** Symbols | 2.41 | 1.41 | 1.75 | 0.79 | 2.25 | 1.22 |
| **MAP** Labels | 2.46 | 1.47 | 1.79 | 0.78 | 2.46 | 1.22 |
| **MAP** Zoom | 2.00 | 1.02 | 1.58 | 0.65 | 1.71 | 0.81 |
| **REP** Contact | 2.00 | 1.06 | 1.67 | 0.82 | 1.58 | 0.78 |
| **REP** CFF | 2.00 | 1.10 | 1.71 | 0.75 | 1.58 | 0.83 |
| **REP** Spot | 1.92 | 1.06 | 1.75 | 0.85 | 1.58 | 0.78 |
| **REP** SitRep | 2.04 | 1.16 | 1.71 | 0.75 | 1.83 | 0.96 |
| **REP** Shell | 1.96 | 1.08 | 2.00 | 1.02 | 1.63 | 0.77 |
| **REP** LOG | 2.04 | 1.23 | 2.08 | 1.06 | 1.92 | 1.10 |
| **REP** Adjust | 2.17 | 1.20 | 2.04 | 1.04 | 1.54 | 0.66 |
| **NAV** Route | 1.96 | 0.96 | 1.88 | 0.90 | 1.54 | 0.72 |
| **SCROLL** Home | 1.96 | 0.91 | 1.79 | 0.88 | 1.58 | 0.78 |
| **SCROLL** Vel | 2.92 | 1.69 | 2.50 | 1.32 | 2.33 | 1.20 |
| **SCROLL** Lock | 2.33 | 1.20 | 1.96 | 1.08 | 1.75 | 0.94 |
| **RECEIVE** | 2.25 | 1.15 | 2.21 | 1.22 | 1.75 | 0.79 |
| **RECEIVE** Show | 2.33 | 1.20 | 2.17 | 1.24 | 1.88 | 0.95 |
| **RECEIVE** Act | 2.46 | 1.44 | 2.04 | 1.12 | 1.83 | 0.87 |
| **SEND** | 2.13 | 1.12 | 1.88 | 0.85 | 1.58 | 0.88 |

Note. All ratings based on seven-point rating scale. Anchors for the ease-of-learning and ease-of-use ratings ranged from extremely easy (1) to extremely difficult (7). For the helpfulness ratings, anchors ranged from extremely helpful (1) to extremely unhelpful (7).

differentiation across the 26 IVIS functions on any of these ratings. Most of the mean ratings for each dimension (learning, use, and helpfulness) fall within a one-rating point range.

For the ease-of-learning ratings, the commanders indicated that the **MAP** Labels, Symbols, Spots, and LOS functions and the **SCROLL** Drag and Vel functions were the most difficult to learn. Many of the report functions were rated as easy to learn.

For the ease-of-use ratings, the commanders suggested that the **SCROLL** Drag and Vel functions, as well as some of the report and **RECEIVE** functions, were hardest to use. The easiest functions to use, on the average, were the **MAP** functions, particularly the overlay, features, and zoom functions.

For the helpfulness ratings, the commanders asserted that the **MAP** Spots, LOS, Symbols, and Labels functions and the **SCROLL** Drag and Vel functions were less critical for mission accomplishment. The **NAV** and report functions were consistently rated as the most helpful.

The learning, use, and helpfulness ratings possessed acceptable reliability. Coefficient alpha, split-half, and intraclass reliability coefficients were all above .90 ($p<.001$).

Other Comments

In addition to completing several ratings, the commanders expressed reactions to IVIS in their responses to six open-ended questions and throughout the soldier after action review and debriefing sessions. These reactions are summarized below.

IVIS Design Recommendations. While the commanders consistently offered praise for the IVIS system and suggested that it should be included in the upgraded M1 tank, many commanders made suggestions for improving the display interface. For example, the commanders consistently criticized the protocols used in the current research for routing reports. The commanders indicated a need to be able to send reports to specific commanders, not just to higher, lower, or all tanks.

Moreover, the commanders indicated dissatisfaction with the IVIS report queuing procedures. The commanders were frustrated over the high number of reports they received with IVIS. They believed that the high number of reports interfered with their ability to survey the battlefield for targets. The commanders also recommended that the queue list reports by priority of most recent report first.

Many of the commanders suggested that report information could be presented graphically on their map display with tank icons and other symbols, rather than only as text. Furthermore, the commanders were not satisfied with the location of the IVIS **RECEIVE** key and requested that it not be located in the variable menu area. Instead of having to exit or cancel a current task or function to read an incoming report, the commanders advised that

the report only temporarily replace the variable menu area. Once reports are read, the commanders proposed that the menu area be replaced with the menu (with entered information intact) used in their previous task.

In addition, some of the commanders requested that an acknowledgement message be displayed to indicate that a report was successfully transmitted and read. Others also requested that filtering procedures be included to reduce the number of duplicate reports housed in the queue. Moreover, greater flexibility was recommended for the report functions. For example, with the current IVIS prototype, a contact or spot report could only refer to one type of enemy vehicle (e.g., tanks). Hence, commanders were forced to send two reports to indicate engagement activities involving multiple types of targets.

In regard to IVIS allocation across the platoon, commander reactions were mixed. Some commanders suggested that the IVIS reporting functions were a hindrance and that every tank should include the IVIS display but without the reporting functions. Conversely, some commanders felt strongly that every tank should include the IVIS display complete with the reporting functions.

Furthermore, the commanders suggested that the own tank and other tank icons depicted on the IVIS map display should be smaller and color-coded to allow rapid differentiation of one tank from another. Distinguishing between the friendly tank icons was particularly difficult--especially when the units were close together, such as during consolidation activities. Some commanders indicated that unit identification information, such as bumper numbers, should be contained within the tank icon or presented when the user touches the particular icon of interest.

In addition, many commanders asserted that FRAGO map overlay lines were too thick and that the **MAP** Overlay function deserves a dedicated function key.

Regarding the **NAV** function, the commanders requested that waypoints sent by other commanders should not automatically replace their existing route waypoints. The need for a procedure for saving alternative routes (e.g., possible change of mission routes) was also indicated by some commanders.

<u>Most and Least Critical IVIS Functions</u>. Consistent with the function helpfulness ratings described earlier, the commanders indicated strong support for most of the IVIS functions, particularly the navigation, map overlay, and reporting capabilities. Many of the commanders asserted that the IVIS map display with mutual POSNAV tank icons was especially helpful for navigating and coordinating unit movement and formations. The commanders indicated that the driver's display allowed their

drivers to navigate without continuous TC direction, which resulted in more time for the commanders to send reports and engage targets. Although not consistent with the objective platoon mission data for battlefield reporting times, some commanders also indicated that the IVIS reporting functions improved the timeliness of their reporting.

While many commanders described the **MAP** LOS, Spots, Symbols, and Labels functions as nice to have, they admitted that they seldom had the time to use these functions. Moreover, the commanders indicated some dissatisfaction with the **SCROLL** functions and with the report routing protocols included in the IVIS prototype. Furthermore, some commanders expressed dissatisfaction with the volume of reports sent over IVIS and the way they were presented. Many commanders admitted to frequently deleting reports from the queue without reading them simply to stop the audible priority tones and to keep the queue from becoming several pages long.

## SIMNET-D Questionnaire Analyses

### Rating Items

The SIMNET-D Questionnaire, administered to each commander in the IVIS and NO IVIS groups, provided the commanders with an opportunity to express their reactions to SIMNET-D and the usefulness of the current test. As part of this questionnaire, the commanders indicated their level of agreement with five statements about the SIMNET-D system. The means and standard deviations across all commanders for these items are included in Table 26.

Overall, the commanders expressed mixed reactions on four of the five rating items. The commanders, on the average, agreed that the SIMNET-D radios were easy to use. However, the commanders were split in their reactions to SIMNET-D breakdowns and to whether they performed as well in SIMNET-D as they did in the field.

### Other Comments

In addition to completing five Likert rating items, the commanders indicated reactions to SIMNET-D and the current test in their responses to five open-ended questions and as part of the after action review and debriefing sessions. These reactions are summarized below.

SIMNET-D Design Recommendations. The commanders offered several suggestions for improving SIMNET-D. These suggestions ranged from very simple design changes that would improve the

Table 26

SIMNET-D Questionnaire: Rating Item Means (M) and Standard Deviations (SD) by Test Condition

| Item | IVIS M | IVIS SD | NO IVIS M | NO IVIS SD |
|---|---|---|---|---|
| 1. There were too many SIMNET-D equipment breakdowns. | 2.8 | 1.4 | 2.0 | 1.3 |
| 2. I think that I did about as well in SIMNET-D as I would do in a real tank. | 2.8 | 1.0 | 3.1 | 1.1 |
| 3. The radios in SIMNET-D were easy to use. | 3.9 | 0.8 | 3.9 | 1.0 |
| 4. I experienced fewer breakdowns in SIMNET-D than I expected to experience. | 3.4 | 0.9 | 3.1 | 1.0 |
| 5. I experienced more equipment breakdowns in SIMNET-D than I usually do in a field training exercise with real tanks. | 2.35 | 1.3 | 2.8 | 1.3 |

Note. Rating based on a five-point rating scale with anchors ranging from strongly disagree (1) to strongly agree (5). There were no significant mean differences by group ($p>.05$).

soldiers' comfort in the simulators (e.g., better radio headset and seat padding) to major system additions (e.g., more vision blocks or an open hatch capability).

The commanders frequently complained that the radio headset, seat, and headrest paddings offered for the tank crew member stations were too hard and resulted in discomfort and pain. Furthermore, some commanders complained about the resolution and sharpness of the tank simulators' sight pictures. The tanks' sights were frequently cleaned and calibrated on commander request throughout this research.

Other commanders also indicated that the SIMNET-D tanks made more noise than a real tank, particularly when one considers that the SIMNET-D crew members wear only headphones rather than CVC

helmets. In addition, some commanders complained about the SIMNET-D M1's fire control system and frequently suggested that the tanks' systems be recalibrated. For example, accurately placing the sight crosshairs on long range targets was especially difficult for many of the soldiers.

Some commanders suggested that the SIMNET-D tanks should include a 50 caliber or coaxial (COAX) machine gun, an open hatch capability, and more vision blocks. Several commanders indicated that with only the rotatable three vision block cupola, it was difficult to navigate and maintain situation awareness.

Finally, some commanders indicated that the reliability of the SIMNET-D vehicles and the simulated combat developments should be improved. There were numerous equipment breakdowns during this research, particularly during the early weeks. These breakdowns often resulted in soldier frustration and long delays.

SIMNET-D Strengths. While the commanders offered many suggestions for improving SIMNET-D, they also expressed many positive reactions to SIMNET-D. For example, many commanders suggested that SIMNET-D provided an excellent environment for practicing command and control tasks, stating that it was just as hard in the field to maintain command and control as it was in SIMNET-D. Moreover, most of the commanders indicated that SIMNET-D provides a valuable means for maintaining or refreshing their battlefield skills between the lengthy delays that often occur between formal field training exercises.

In regard to the usefulness of the current IVIS experiment, the majority of the commanders indicated support and encouragement for SIMNET-D based combat development research. However, the commanders indicated that SIMNET-D tests should not replace, but complement, field tests. Some commanders indicated the need for a longer crew and platoon training period to ensure that the *ad hoc* crews could work well together before testing. Overall, however, the commanders were especially satisfied to have had the opportunity to evaluate IVIS and to suggest improvements before the system was actually built.

## Correlation Analyses

Correlation analyses were performed to examine the relationships between selected commander background measures and the $C^3$ exercise criterion and normative-oriented composite measures. In addition, for the IVIS-equipped commanders, analyses were performed to assess the relationship between the IVIS training evaluation and commander background and performance.

Table 27 presents the unique soldier background and C3 exercise performance correlation matrices for the IVIS and NO IVIS commanders. For the 24 NO IVIS commanders, the ASVAB GT and LNST scores correlated significantly with at least half of the composite $C^3$ performance measures. Higher GT scores were associated with better own location reporting, battlefield reporting, and CFF performance across the NO IVIS commanders. Moreover, better own location reporting, battlefield reporting, CFF, and FRAGO performance were related to higher land navigation test scores for the NO IVIS commanders. No significant correlations were detected between the commander background and $C^3$ exercise performance measures for the 24 IVIS commanders.

Table 28 presents the correlations, for the IVIS commanders, between the background and IVIS training evaluation measures. Overall, computer experience self-ratings correlated significantly with five of the eight training measures. Greater computer experience was related to better IVIS proficiency after training and after testing, as indicated by the IVIS commanders' IVIS Performance Test scores. Moreover, the commanders with greater computer experience rated the IVIS functions as easier to learn, easier to use, and more helpful.

Table 29 shows the correlations between the IVIS training evaluation and $C^3$ performance measures for the IVIS-equipped commanders. Overall, across both the normative and criterion-oriented composite measures, only one correlation coefficient was significant. Higher IVIS Knowledge Test scores were associated with better battlefield reporting performance as measured using a criterion-oriented composite.

## Discussion

### Performance Effects of IVIS

Overall, the IVIS test results suggest that IVIS should be included in the upgraded Block II M1 Abrams tank. Tank crews and platoons who used IVIS performed significantly better on every composite performance measure evaluated than baseline crews and platoons who used conventional $C^3$ and navigational tools, such as a radio, paper map, compass, and protractor.

Crews with IVIS required less than half the time of NO IVIS crews to plan and execute the Armor small unit $C^3$ exercise. Moreover, the IVIS-equipped crews sent more timely, complete, and accurate own-location and battlefield reports, and successfully executed more exercise change of mission, obstacle bypass, battle position, and CFF tasks.

Table 27

Correlations Between Selected Soldier Background and $C^3$ Exercise Performance Measures By Treatment Group

**NO IVIS Commanders: Criterion-Oriented Composite Measures**

| | GT | LNST | JOB EXP | COMP EXP | SIM EXP |
|---|---|---|---|---|---|
| ZTIME | .12 | .03 | -.33 | .08 | .08 |
| OWNREP | .50* | .62* | .05 | .22 | -.15 |
| OTHERREP | .48* | .67* | -.09 | .45* | .01 |
| CFF | .69* | .53* | -.17 | .11 | -.28 |
| FRAGO | .25 | .45* | -.03 | -.01 | -.09 |
| BP | .25 | .29 | -.05 | -.02 | -.30 |

**NO IVIS Commanders: Normative-Oriented Composite Measures**

| | GT | LNST | JOB EXP | COMP EXP | SIM EXP |
|---|---|---|---|---|---|
| ZTIME | .12 | .03 | -.33 | .08 | .08 |
| OWNREP | .50* | .62* | .05 | .22 | -.15 |
| OTHERREP | .56* | .77* | -.17 | .50* | -.05 |
| CFF | .59* | .62* | -.22 | .27 | -.18 |
| FRAGO | .47* | .48* | -.06 | -.02 | .07 |
| BP | .37 | .36 | -.10 | -.04 | .17 |

**IVIS Commanders: Criterion-Oriented Composite Measures**

| | GT | LNST | JOB EXP | COMP EXP | SIM EXP |
|---|---|---|---|---|---|
| ZTIME | .19 | .26 | -.35 | .13 | .24 |
| OWNREP | .17 | .17 | -.36 | .18 | .22 |
| OTHERREP | .13 | .35 | .07 | -.03 | .36 |
| CFF | .35 | .06 | .06 | .13 | .16 |
| FRAGO | -.30 | .08 | -.20 | .01 | .17 |
| BP | .32 | .34 | -.35 | .06 | .13 |

**IVIS Commanders: Normative-Oriented Composite Measures**

| | GT | LNST | JOB EXP | COMP EXP | SIM EXP |
|---|---|---|---|---|---|
| ZTIME | .19 | .26 | -.35 | .13 | .24 |
| OWNREP | .17 | .17 | -.36 | .22 | .18 |
| OTHERREP | .22 | .31 | -.02 | -.02 | .28 |
| CFF | .36 | .12 | .15 | .14 | .16 |
| FRAGO | .17 | .33 | -.38 | -.12 | .24 |
| BP | .39 | .32 | -.24 | -.12 | .16 |

* statistically significant ($p<.05$)

Table 28

Correlations Between Selected Soldier Background Measures and IVIS Training Evaluation Measures for IVIS-Equipped Commanders

| | GT | LNST | JOB EXP | COMP EXP | SIM EXP |
|---|---|---|---|---|---|
| IVIS Knowledge | .13 | .31 | -.27 | -.32 | .39 |
| IVIS Perf 1 | .15 | .22 | -.34 | .64* | .30 |
| IVIS Perf 2 | -.06 | .35 | -.31 | .46* | .25 |
| Effectiveness | .23 | -.30 | .17 | -.15 | <.01 |
| Training Time | -.06 | -.13 | .19 | .15 | .30 |
| Ease-of-Learning | -.12 | -.12 | .34 | -.53* | .03 |
| Ease-of-Use | -.10 | -.10 | .37 | -.57* | <.01 |
| Helpfulness | -.05 | -.05 | .38 | -.62* | .09 |

* values indicate statistically significant correlation ($p<.05$)

Table 29

Correlations Between IVIS Training Evaluation and $C^3$ Exercise Performance Measures for IVIS-Equipped Commanders

**Normative-Oriented Composite Measures**

| | ZTIME | ZOWN | ZOTHER | ZCFF | ZFRAGO | ZBP |
|---|---|---|---|---|---|---|
| IVIS Knowledge | .35 | .23 | .41 | .06 | .21 | .34 |
| IVIS Perf 1 | .03 | .23 | .31 | .20 | -.07 | .07 |
| IVIS Perf 2 | .19 | .40 | .29 | .18 | -.06 | .07 |
| Effectiveness | .01 | .02 | -.40 | .03 | .15 | .01 |
| Training Time | .11 | .04 | .24 | -.13 | .29 | .19 |
| Ease-of-Learning | -.26 | -.11 | -.11 | -.12 | .31 | .28 |
| Ease-of-Use | -.25 | -.15 | -.01 | -.17 | .22 | .24 |
| Helpfulness | -.14 | -.15 | -.01 | -.31 | .27 | .19 |

**Criterion-Oriented Composite Measures**

| | ZTIME | OWN | OTHER | CFF | FRAGO | BP |
|---|---|---|---|---|---|---|
| IVIS Knowledge | .35 | .23 | .50* | .01 | -.12 | .22 |
| IVIS Perf 1 | .03 | .23 | .29 | -.14 | -.28 | .06 |
| IVIS Perf 2 | .19 | .40 | .29 | .11 | -.19 | -.01 |
| Effectiveness | .01 | .02 | -.27 | .02 | .21 | -.02 |
| Training Time | .11 | .04 | .31 | -.18 | .40 | .32 |
| Ease-of-Learning | -.26 | -.12 | -.20 | -.17 | .14 | .17 |
| Ease-of-Use | -.25 | -.15 | -.17 | -.20 | .04 | .22 |
| Helpfulness | -.14 | -.15 | -.04 | -.35 | .24 | .27 |

* statistically significant ($p<.05$)

Platoons with IVIS, compared to platoons without IVIS, successfully completed the offensive and defensive combat missions more frequently, completed more mission segments, successfully executed more FRAGOs, and sent more accurate own-location and battlefield reports.

These differences are especially compelling for at least five reasons. First, the current experiment included a limited number of crews and platoons and hence possessed, at best, a level of statistical power suitable for detecting only large group differences. Despite the limited power of this research, the IVIS-equipped crews and platoons who participated in this experiment demonstrated significantly better performance on every composite measure collected. Moreover, Armor platoon performance improvements with IVIS persisted equally across both offensive Movement to Contact/Hasty Attack and defensive Hasty Defense missions, as well as across resupply, withdrawal, Hasty Defense, and Movement to Contact/Hasty Attack mission FRAGOs.

Second, these differences were consistent across alternative composite performance scoring strategies. Whether composite measure development strategies were based on current military standards, task criticality, and task contingencies (i.e., criterion-oriented) or based solely on absolute performance scores (i.e., normative-oriented), the results showed strong IVIS crew and platoon performance improvements. On every criterion and normative-oriented composite measure evaluated, the IVIS crews and platoons performed about twice as well as conventionally-equipped baseline units.

Third, IVIS not only improved crew and platoon mean performance, but also resulted in more consistent performance. For example, standard deviations for the performance of IVIS crews were frequently more than two and three times smaller than the standard deviations associated with baseline crews. The consistent performance of IVIS-aided commanders is important in the conduct of multi-echelon military operations in which each individual unit's mission is integral to overall force effectiveness.

Fourth, the post hoc group equivalence analyses detected no significant group differences, overall or by test position, on any of 15 experience, education, knowledge, and aptitude measures collected. These soldier background measures included job experience, NTC experience, Armor experience, last field exercise experience, SIMNET-D experience, COFT experience, ASVAB CO and GT scores, LNST score, SIMNET-D Knowledge Test score, current tank position, formal Armor education, computer experience, current MOS, and current military grade. Moreover, the soldiers evaluated appear to have possessed backgrounds consistent with those expected in active Armor crews and platoons.

Finally, the $C^3$ exercise and offensive and platoon combat missions were designed by the researchers in concert with experienced Armor SMEs. These SMEs included a USAARMS instructor, active Armor platoon leaders, platoon sergeants, and tank commanders, an Armor test officer, and an on-staff retired Armor Lt. Colonel. These exercises reflected current military tactics, operating procedures, mission requirements, doctrine, and expected future battlefield conditions. The Movement to Contact/Hasty Attack and Hasty Defense missions chosen, for example, are regarded as perhaps the most frequent, demanding, and critical missions of the Maneuver Force. Both the Hasty Attack and the change of mission, FRAGO, are central to the doctrinal assumptions of the AirLand Battle--speed, agility, penetration, and synchronization.

## Intervehicular Reporting Requirements

While the IVIS-equipped platoons consistently performed better than the conventionally-equipped platoons, the platoon IVIS usage measures evaluated in this research indicated some disturbing reporting patterns. The IVIS commanders, on the average, sent far too many reports--nearly one report every 30 seconds or about 300 reports across each mission. As a result, the IVIS commanders, particularly the tank commanders, maintained unacceptable queue sizes. Moreover, despite the visual and auditory warnings that occurred after IVIS reports entered a commander's queue, the commanders took nearly four minutes, on the average, to call up each report.

These disturbing IVIS usage patterns can be attributed to several factors. First, when a baseline commander sent a battlefield report over the platoon radio network, all of the other commanders in the platoon could simultaneously hear the report. Moreover, unlike the IVIS commanders, the baseline commanders were not required to touch a **RECEIVE** key to hear the message. In most cases, the listening baseline commanders could continue with their current battlefield tasks (e.g., searching for and engaging targets) without interruption. Furthermore, if the report sufficiently described current battlefield activities, the listening commanders did not duplicate the report before it was forwarded to the company commander. Hence, platoon commanders using radios often sent only one or two reports across the platoon for each battlefield event.

The platoons with IVIS, however, did not simultaneously hear other commanders' reports while performing other activities. Instead, the commanders had to continually interrupt their current activities and call up reports from their queue to stay equally informed. As a result of this inconvenience, however, the IVIS commanders called up reports at different rates and thus operated under varying levels of battlefield awareness. Also,

unaware that another commander had already reported the platoon's current activity, the IVIS commanders often duplicated reports. As a result, platoon leaders were required to repeatedly consolidate numerous reports (about nine reports per battlefield event) before transmitting them to higher units.

While platoon leaders, on the average, were able to successfully maintain an empty queue throughout the combat missions, they consistently indicated that the process of calling up, reading, and consolidating duplicated or only slightly variable battlefield reports was frustrating, difficult, and time consuming. Furthermore, both the platoon leaders and tank commanders admitted that they spent more time looking at IVIS than they tactically should have. The IVIS commanders suggested that with experience, however, they learned to better allocate their time between IVIS and other tasks.

Surprisingly, despite the difficulties commanders experienced calling up IVIS reports and maintaining uniform situation awareness, the platoons were still able to send reports, on the average, as fast and complete as the baseline platoons, but with greater accuracy. Moreover, despite their concerns, the IVIS commanders, on the average, contradicted the objective data and suggested that they could send reports faster with IVIS than they could using a radio. This contradiction, however, could reflect the difficulty commanders have been found to experience accessing radio networks and transmitting messages in the field (Polk & Lee, 1987). Some radio communication problems (e.g., jamming, interference, other unit traffic) were not simulated or evaluated in this research.

These disturbing IVIS usage patterns (i.e., too many reports, large queues, long time to call up reports) suggest several IVIS interface design and training needs. These needs are described below.

<u>Interface Design Recommendations/Needs</u>. The most consistent concern voiced by the IVIS commanders and loader assistants was that the IVIS report queuing protocols need to be completely redesigned. Probably the most important lesson learned about the IVIS system as part of this research is that the intervehicular reporting functions included in IVIS deserve additional, more refined research. The automation of battlefield reporting changes nearly every aspect of reporting.

<u>Emotionless Reports</u>. The commanders often voiced reservations about the inability to express emotion in an IVIS report. Commanders could not distinguish between the immediately needed CFF request and the "nice to have" CFF request. Also, in responding to CFF and other battlefield reports, listening commanders were not required to acknowledge receipt or action. Hence, it was very easy for receiving commanders to ignore

reports, for sending commanders to forget they had sent reports, or for sending commanders to repeat reports because they believed the commander may not have received or read the report. Commanders, in fact, often felt compelled to immediately follow-up urgent CFF requests with radio pleas.

Graphic Report Presentation. In redesigning the IVIS display, combat developers should focus, it seems, on limiting the requirements of users to call up information. A possible approach would be to evaluate the utility of graphically displaying report information (e.g., via colored symbols) on the IVIS map display, rather than storing reports in a queue. Instead of sending a report to the IVIS queue which says "CONTACT Tanks ES614849", the IVIS display could simply display a red flashing tank symbol on the IVIS map display at the estimated grid location.

Similarly, a mortar or artillery bombing symbol could be used to represent indirect fire activity. Report information presented graphically, without a queue, may potentially allow commanders to maintain more uniform levels of situation awareness through bypassing the need for TCs to call up the report(s) themselves. TCs will also see the results of other reports on the same battlefield event, and hence, reduce the duplication of reports.

Of course, the graphic presentation of report data presents other research questions. For example, how long should report data be displayed? What report information should be displayed? Would graphic report presentation clutter the map? Could report information be stored? Would there be some indication of the time information was received? How often should display information be updated? Who will be responsible for digitizing the report information? Or if automatically digitized, who would authorize and coordinate its transmission? Will graphic presentation of report data reduce duplication of reports? Would there be an auditory and/or visual symbol to alert the TC that something new has appeared on his map? What is the best way to graphically display unique report information?

Report Filtering. To reduce the number of duplicated or only slightly variable reports, there is a need for IVIS to filter reports. For example, often during the platoon exercises, each of the four platoon tanks would send a spot report immediately after target destruction. These reports may include the same "what" information (e.g., tanks), but variant estimated "count" (e.g., three tanks) and grid location information (e.g., +/- 200 meters). These reports may be relayed and recirculated several times within the platoon. To further complicate matters, at the platoon level, the platoon leader may incorrectly assume that each unit has sent an accurate report of its own unique engagements: a common occurrence in this research. Hence, in

preparing the spot report for submission to the company commander, the platoon leader may simply transmit a report reflecting all four platoon-level reports; what might have in reality been only a three-tank engagement may ultimately be reported as a 12-tank event. Moreover, what may have occurred only to the northeast of the platoon could be reported as a wide sweeping enemy attack from all sides.

Potential filters could be guided by a set of basic decision rules which accept or reject report information for presentation. For example, at the platoon level, spot report locations within 500 meters may be displayed as one report symbol on the map. Determining these decision rules may require additional research, continual Armor SME guidance, and flexible IVIS prototypes (e.g., rapid prototyping experiments). This report duplication problem may also be resolvable via additional IVIS training, especially training aimed at improving the level of intercommunications within the platoon. Moreover, the problem emphasizes the need for specific IVIS operating procedures within and across units.

Report Routing. Many IVIS commanders suggested the need for more flexible report routing protocols. Using the current IVIS prototype, the commanders had no control over where reports were transmitted once sent. In all cases, report routing was based on strict, default protocols. When platoon leaders sent reports, the information was immediately directed to the company commander and the other platoon vehicles. When tank commanders sent reports, the information was directed only to the other platoon vehicles. These routines could present some rather interesting "loops" or "boomerangs"; a commander could send a report and, as a result of its recirculation by other commanders, receive his own report only seconds later. Ultimately and within a matter of moments, what might start as three unique reports within the platoon can triple into nine reports in each commander's queue through report revision and recirculation.

System/Function Allocation. The IVIS-equipped commanders consistently indicated that the most essential features of IVIS were the map terrain display with vehicle icons (mutual POSNAV), the "route designation" function, and the "map overlay" function. These functions, according to the commanders, resulted in the greatest benefits to combat performance. Some commanders even suggested tank commanders should be provided, by default, with only the position navigation functions. Platoon leaders, however, should be provided with functions for both navigation and reporting. Only as a backup to platoon leader injury or IVIS equipment failure would tank commanders have access to IVIS intervehicular functions. The commanders' proposed allocation strategy and other approaches should be evaluated to determine the best mix of tactical assets within the platoon. This could be done by unit SOP.

Training Concerns. The units in the current experiment suggested numerous unique methods for working around some of the report queuing and routing concerns described earlier. Some commanders asserted that operating procedures should be based on using both an IVIS and radio reporting capacity. For example, tank commanders could be required to send battlefield reports and other information over the radio. Platoon leaders, however, could be the principal report consolidator and input and transmit this information via IVIS. Others suggested that IVIS should only be used for sending less critical reports, such as logistics reports. These optional methods and others should be evaluated to develop optimal procedures and training requirements.

POSNAV versus IVIS

The principal difference between the POSNAV terrain map display evaluated by Du Bois and Smith (1989) and the IVIS display evaluated in the current research is the intervehicular reporting functions. Both POSNAV and IVIS included a map display area with own-vehicle icon, an own location window, and map manipulation and navigation functions. IVIS, however, also included mutual POSNAV capabilities (i.e., icons for both own and other friendly vehicles), as well as functions for preparing, transmitting, receiving, and relaying reports. POSNAV-equipped platoons used a radio for transmitting all reports. Both the POSNAV and IVIS evaluations involved conducting missions in daylight SIMNET-D environments and included no jamming or other interference of voice radio networks. Hence, comparing the platoon combat mission data from the earlier POSNAV effort with this effort allows one to examine the potential incremental benefits of these IVIS intervehicular reporting functions.

However, while the missions used in this IVIS effort and the previous POSNAV research were both Movement to Contact/Hasty Attack missions, they were conducted in different SIMNET-D terrain settings with unique OPORDs and task requirements. Consequently, conclusions drawn from this comparison cannot be attributed solely to the POSNAV-IVIS differences since these factors are confounded with soldier sample and scenario variations. They nevertheless indicate trends and insights, as well as directions, for further research.

Table 30 presents the platoon combat mission performance means and standard deviations for those measures collected during both the current experiment and the previous POSNAV experiment (Du Bois & Smith, 1989). Data are presented for offensive platoon combat mission performance, as no defensive missions were administered as part of the POSNAV experiment.

Table 30

POSNAV versus IVIS: Means (M) and Standard Deviations (SD) for Platoon Combat Mission Performance

| Measure | POSNAV M | POSNAV SD | IVIS M | IVIS SD |
|---|---|---|---|---|
| Percent of Mission Segments Executed | 100% | 0% | 100% | 0% |
| Time to Execute Mission Segments | 15min | 2min | 11min | 2min |
| Accuracy of SPOT Report Grid | 384m | 79m | 203m | 134m |
| Time to Send SPOT Report | 50sec | 21sec | 114sec | 47sec |
| Accuracy of SHELL Report Grid | 369m | 69m | 419m | 157m |
| Time to Send SHELL Report | 38sec | 14sec | 42sec | 11sec |
| Accuracy of OWN Location Grid | 4m | 2m | 4m | .5m |
| Time to Report OWN Location | 12sec | 9sec | 11sec | 5sec |
| Percent of FRAGOs Executed | 100% | 0% | 100% | 0% |
| Time to Plan and Execute FRAGOs | 37min | 11min | 30min | 7min |
| Percent of Time Used Vision Blocks | 52% | 9% | 38% | 8% |
| Percent of Time Used Paper Map | 10% | 5% | 10% | 10% |
| Percent of Time Used Display | 38% | 7% | 52% | 7% |

Note. POSNAV means and standard deviations taken from Du Bois and Smith (1989). IVIS means and standard deviations reflect the current research findings. All measures based on offensive mission performance.

Overall, despite having intervehicular reporting functions, the IVIS platoons do not appear to have performed offensive platoon combat missions any better across the reporting and execution measures evaluated than the platoons equipped with POSNAV. In fact, the IVIS platoons took more than twice the time of POSNAV platoons to report selected battlefield activities (i.e., spot reports). This longer time to send reports for IVIS-equipped commanders appears to be the result of the report

reception and other intervehicular reporting concerns outlined earlier.

Furthermore, the IVIS platoons spent less time looking at the battlefield through their vision block and sights and more time looking at their new display than the POSNAV platoons. Apparently, the additional IVIS functions result in no significant improvement in reporting or execution performance but demand additional IVIS commander time. Also, both IVIS and POSNAV platoons devoted equal time to their paper maps.

This comparison indicates the need for further research to investigate the unique contributions of IVIS. At best, the prototype IVIS evaluated in this research appears to have provided no additional performance contributions over those provided by the POSNAV display and functions. With redesign (e.g., graphic report presentation, report filters, revised system/function allocation strategies) and additional training, however, IVIS may provide important contributions to combat performance above those provided by the POSNAV functions and tools. Overall, this research indicates the necessity of early concept exploration research for determining the functional requirements and interface design of IVIS.

## Training Implications of IVIS

Several training implications of IVIS were identified during the crew and platoon testing. First, despite the successful performance of most commanders on the IVIS Knowledge Test and IVIS Performance Test administered after training, the commanders indicated the need for additional hands-on training with IVIS. This need was also demonstrated by the consistent proficiency improvements of the IVIS-equipped commanders on the post-exercises IVIS Performance Test. Moreover, if possible, future IVIS training lectures should be supported with static and, preferably dynamic, PC-based IVIS prototypes.

The commanders demonstrated the least proficiency and knowledge of those functions falling in one of three categories: (a) those nice to have functions that were seldom used (e.g., **MAP LOS, LABELS, SYMBOLS**), (b) those functions that required several procedural steps to execute (e.g., **RECEIVE ACT, SHOW**), and (c) those that were difficult to understand or to manually control via the touch screen (e.g., **SCROLL VEL, DRAG**).

### Tactical Training

Learning to use IVIS may have been generally easy, but learning to use IVIS effectively with respect to tactical deployment is a more complex issue. For example, platoon leaders--after receiving a mission OPORD--routinely plan their

mission, issue their plans, and control and coordinate all platoon actions. While the route designation function of IVIS may be readily adapted to specify the platoon course of action, no doctrinal guidelines have been established for exploiting and standardizing its tactical utilization.

Furthermore, IVIS crews and platoons must learn to use the IVIS navigation information while also maintaining effective cover and concealment and unit formations. Drivers and commanders may too often be tempted to simply follow the dictates of the IVIS "Steer-to" display without regard to terrain and potential enemy avenues of approach and hiding positions.

Moreover, the vision blocks and sights usage data suggest that future IVIS training programs should include a greater emphasis on ensuring that tank commanders can effectively integrate the use of IVIS into a platoon combat mission. The IVIS-equipped commander cannot compromise his crew members by spending less "quality" time looking out the tank's vision blocks and sights. Both on-board observer ratings and TC self-ratings consistently show that commanders with IVIS spent less time looking out the tank's vision blocks during the crew $C^3$ exercise and the offensive and defensive platoon combat missions than those without IVIS. The commanders themselves indicated that they spent more time looking at and using the IVIS display than is tactically sound. This could have serious implications on the ability of the tank crews and platoon to detect and engage targets, search for firing positions, and maintain command and control. Future IVIS training programs should include time for preparing commanders to integrate IVIS with other mission tasks.

These driver "Steer-to" and commander vision block use concerns, however, need to be evaluated in a more extended operational training setting. The crews and platoons in this research were given one-and-a-half days of training on the IVIS display and control features before actual testing began. Crews and platoons routinely equipped with IVIS may develop better operating procedures and guidelines for effectively integrating the use of IVIS with other critical combat mission behaviors. A longer training program--one which allowed the tank crews and platoons more opportunities to become familiar with the system in more diverse situations--appears especially important in assuring this IVIS integration. Moreover, trainers and evaluators must identify expert IVIS users: those who have developed routines which maximize the contributions of IVIS while not compromising other battlefield requirements. The operating procedures and behaviors incorporated by these expert users could then be modeled and taught to other commanders.

The vision block data are also based on a relatively imprecise measure of commander behavior. To avoid having data collectors make inferences, for example, about whether commanders

were focusing more on terrain features than enemy units, the data collectors were trained to collect data concerning where the commander was looking, not what he was specifically looking at. Furthermore, these vision block usage ratings do not reflect the effectiveness in which the commanders used their vision blocks and sights. While baseline commanders may have spent more time looking out the tank's vision blocks than the IVIS-aided commanders, the IVIS commanders may have used their vision blocks and sights more effectively. For example, the NO IVIS commanders may have spent more time looking out the vision blocks for navigation purposes, while the IVIS commanders may have spent more time surveying the battlefield for targets. Future research should examine these important, but complex, issues.

Additional IVIS training time may better ensure that tank commanders and other crew member have an opportunity to learn to trust the IVIS system. The crew members in the current experiment frequently commented that they had to convince themselves that the system actually worked.

Degraded Modes

The commanders indicated that critical $C^3$ tasks could be performed with less difficulty in SIMNET-D with IVIS than they could in the actual tank in the field without IVIS. This is not surprising. IVIS automates many of these critical tasks for the commander. Nevertheless, future IVIS training should continue to include basic $C^3$ and navigation skills. The commanders must always be prepared for IVIS system breakdowns or malfunctions. Commanders must learn to rely on IVIS with some restraint so that they can quickly realize when the system has failed and revert to more traditional means of $C^3$ and navigation. This is especially important considering the difficulty soldiers will likely experience when reverting to conventional $C^3$ procedures on an NBC, closed-hatch, limited visibility battlefield with less secure radio transmissions. Thus, commanders cannot forget how to read maps, navigate, and determine battlefield locations.

Personnel Requirements

An encouraging finding from this research is the absence of any significant correlations between soldier job experience, SIMNET-D experience, LNST, and ASVAB GT scores with training performance and $C^3$ exercise performance for the IVIS commanders. Apparently, IVIS is an equalizer. Whereas the battlefield performance of commanders in the NO IVIS group was often significantly associated with soldier aptitude and skill measures, IVIS-aided commanders, regardless of aptitude and land navigation skills, performed $C^3$ tasks with uniform success. Nevertheless, additional research designed specifically to assess IVIS personnel requirements may indicate that more experienced,

smarter tank commanders develop and use better operating procedures when incorporating IVIS into a tactical operation.

The correlations between commander computer experience and several IVIS training measures, including IVIS Performance Test scores and IVIS ease-of-learning, ease-of-use, and helpfulness ratings, however, indicate the importance of providing effective hands-on training. For many commanders, IVIS represents their first exposure to using computers. Hence, IVIS training should focus on providing these commanders with a basic understanding of computers as well as free play and structured hands-on practice. Computer experience may also have improved the IVIS commanders' willingness to initially accept IVIS as helpful. Nevertheless, IVIS should ultimately be designed so simply that the users do not know that a computer is even involved; then IVIS would not be intimidating to those without prior computer experience. Despite the relationship between computer experience and training, however, the commanders' computer experience levels were not related to their $C^3$ exercise performance.

Duty Specific

The reduced radio traffic and the capability of drivers to navigate autonomously raise important training and doctrinal issues. First, tank commander training and experience with IVIS-equipped tanks must promote their trust of the operational capabilities and reliability of the IVIS system. Commanders' confidence in the system's reliability and in the drivers' proficiency in interpreting the IVIS display and tactically executing the assigned routes should substantially free commanders to shift their attention to other mission critical tasks, such as planning, engaging, and coordinating crew and platoon performance.

The potential for drivers to navigate independently will require revisions of current driver training programs, Armor doctrine, and standard operating procedures (SOPs). Driver training programs should ensure that drivers can clearly comprehend the data provided on the driver's display. Drivers should also be trained to navigate independently for an extended period of time and distance (i.e., between route waypoints). This autonomy is quite unlike the high rates of communications between tank commanders and drivers typical of conventional navigation procedures.

Training should also emphasize the requirements for effective information sharing and coordination of IVIS waypoint updating between the driver and tank commander. The IVIS prototype evaluated did not automatically update the driver's display as waypoints were reached. As waypoint 1 was achieved, for example, the data for waypoint 2 was not automatically directed to the driver's display. Users preferred that the

commanders be left in control of this function. Nevertheless, on at least two occasions during the $C^3$ exercise, a driver reached a waypoint and then continued on without informing the commander or receiving the new waypoint. Unfortunately for these crews, an NBC area was only about 500 meters from the waypoint. Before the commander could recognize the error, the crew entered the NBC area. Hence, driver and tank commander coordination, trust, and standard operating procedures are essential to the success of IVIS-equipped units.

The reduced intervehicular radio traffic that results from using IVIS may also impact on the situation awareness of the tank loaders, gunners, and drivers. Instead of having the capability to overhear all platoon radio communications, the tank gunners, drivers, and loaders in IVIS-equipped tanks must solely rely on the intercom communications relayed by the commander to maintain situation awareness. IVIS communications are silent for these crew members. Hence, commanders must ensure that they keep their crew members informed throughout their tactical operations.

### Extended Operations

Finally, IVIS's potential for enhancing the Armor requirements for low visibility (e.g., smoke, night, NBC, fog, closed-hatch) combat operations will have far-ranging training and doctrinal implications across the entire AirLand Battle.

## IVIS Design Recommendations

In addition to the IVIS design recommendations and needs described earlier for resolving IVIS intervehicular reporting problems, other commander, research assistant, and test administrator IVIS redesign suggestions were collected. These recommendations are summarized in Appendix J.

Overall, design recommendations are presented for improving the IVIS report queuing, routing, and receiving protocols, the vehicle icons, the map scrolling functions, the touch screen, the reporting functions, the navigation functions, vehicle heading indicators, and overall system performance.

## Summary and Conclusions

Overall, the current research suggests that IVIS will significantly improve the performance of tank crews and platoons. Crews and platoons with IVIS completed a crew $C^3$ exercise and offensive and defensive platoon combat missions in a simulated daylight battlefield setting more effectively on 11 of 11

composite performance measures evaluated than crews and platoons without IVIS. The methodology as described, we believe, provides an internally valid basis for substantiating the potential impact of IVIS on small unit performance.

Nevertheless, the results indicate several IVIS design needs, particularly with respect to intervehicular reporting functions. As currently designed, the primary impact of IVIS appears to result from the terrain map display, own unit vehicle icons, and navigation functions (i.e., POSNAV). Further research must evaluate optional design strategies, including graphic report presentation, revised report routing protocols, and different system/function allocation mixes. Moreover, numerous less significant IVIS redesign requirements were identified.

Three important limitations of the current effort must be noted, however, with respect to the external validity of these findings. First, the current research findings hinge strongly on the relationship between crew and platoon performance in SIMNET-D and in the real world. This relationship has yet to be completely validated.

Second, the current research did not use intact crews and platoons. Instead, collections of qualified soldiers were assigned to tank crews and platoons. Nevertheless, non-intact unit arrangements may better represent the force mobilization and combat attrition demands common to the Armor force in war.

Finally, the current research was not conducted to evaluate one of the principal potential benefits of IVIS: the ability to send digitized and more secure radio traffic. In the current experiment's crew and platoon exercises, enemy intelligence and jamming capabilities were not included. These capabilities and their resultant impact on conventional small unit $C^3$ performance might better demonstrate the far-ranging benefits of IVIS on mission success.

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Appendix A

Offensive Combat Mission Materials

**TACTICAL MISSION ALPHA - *OFFENSIVE MISSION***

**OPERATIONS ORDER**

**ORIENTATION:** You are 1/A/1-14 Armor (AR) located in ASSEMBLY AREA (AA) STONE at ET593004.

**SITUATION:**

A. <u>ENEMY</u>: Enemy elements of the 7th Motorized Rifle Division (MRD) have broken contact and withdrawn to the south to establish hasty defensive positions vicinity of Irvington, Kentucky. The enemy has built a Division Security Zone consisting of a reinforced motorized rifle battalion in a combat security role. Ground and air reconnaisance have failed to locate any elements of the security zone, but we can expect to encounter individual observations posts. There will likely be company hasty defensive positions 2 to 3 kms behind the observation posts. The enemy is equipped with T-72s and BMPs. The enemy is at 60 percent strength and has not used chemical weapons within the last 48 hours.

B. <u>FRIENDLY</u>:

(1) Task Force (TF) 1-14 AR conducts a Movement to Contact to OBJECTIVE GOLD* at ________ hours, to gain and maintain contact with withdrawal forces and to destroy any enemy combat security detachments in sector. On order, we will continue the attack to the south.

(2) Team Charlie (C), followed by team Bravo (B), is on our right, to secure OBJECTIVES MINE and ROCK.

(3) TF 1-81 Infantry (INF) is on our left, to secure OBJECTIVE HAWK.

(4) Battalion scouts will conduct a zone reconnaissance with concentration on AXIS SILVER and AXIS STEEL.

(5) 1-42 Field Artillery (FA) is in direct support. TF 1-14 AR has priority of fires.

*OBJECTIVE GOLD is OBJECTIVES MINE, ROCK, and ORE.

C. <u>ATTACHMENTS/DETACHMENTS</u>:

(1) Companies C and Delta (D) are detached and the TF has received Company C, 1-81 INF.

(2) 3rd plt, Co. Alpha (A) is detached and we have received 3rd PLT (mechanized) Company C, 1-81 INF.

**MISSION:** Team A, TF 1-14 AR conducts a Movement to Contact along AXIS STEEL at _______ hours, (date), to PHASE LINE (PL) BRASS to support by fire on OBJECTIVES ROCK and ORE. On order, sieze OBJECTIVE ORE. On order, continue the attack south.

**EXECUTION:**

A. <u>COMMANDER'S INTENT</u>:

Using well concealed routes, I want to move along AXIS STEEL. I want to eliminate all enemy vehicles before they have a chance to report our size and exact locations. Use indirect fire as much as possible. When the team is prepared to assault OBJECTIVE ORE, I want the INF to move to BC 2203 and start rooting out enemy vehicles from their fighting positions. Once this is accomplished, 1st and 2nd PLTs will assault to complete destruction of the enemy.

B. <u>CONCEPT OF OPERATION</u>:

(1). <u>MANEUVER</u>: As contact is possible south of LINE OF DEPARTURE (LD) COPPER, the company will cross LD COPPER in wedge formation. If contact is made prior to PL BRASS, the element making contact will, on order, maneuver to destroy the enemy force. Upon arrival at PL BRASS, 1st PLT will occupy overwatch position vicinity of checkpoint (CP) 6 and orient on OBJECTIVE ORE. 2nd PLT will occupy overwatch position vicinity of CP 10 and orient on OBJECTIVE ROCK. 3rd PLT (mech) will move to CP 8, and prepare to assault to BC 2203. Be prepared to sweep thru OBJECTIVE ORE. 1st and 2nd PLTs, on order, will assault OBJECTIVE ORE to CP 4 and 5, respectively. The company will consolidate on OBJECTIVE ORE with three platoons abreast. On order, the TF will continue the attack south. You are the lead element in the A company wedge. You are followed by 2nd and 3rd platoons.

(2) FIRES:

a. Artillery for Team A is on request only.
b. Send all calls for fire through me.
c. Priority of fires initially to 1st PLT.
d. All Target Reference Points (TRPs) are registered pre-plots.
e. Designated artillery targets as per your overlay.

(3) SPECIFIC INSTRUCTIONS:

1st Platoon (Red)

a. Lead element in company wedge, moving along AXIS STEEL.
b. Upon securing CP 4, OBJECTIVE ORE, orient south between TRPs 104 and 105.
c. Do not bypass any enemy resistance.

2nd Platoon (White)

a. Left element in company wedge, moving on AXIS STEEL.
b. Upon securing CP 5, orient south between TRPs 104 and 105.
c. Do not bypass any enemy resistance.

3rd Platoon (Mech) (Green)

a. Right element in company wedge, moving on AXIS STEEL.
b. On order, move to CP 8 and prepare to assault BC 2203.
c. Dismount INF and clear OBJECTIVE ORE on order.
d. Upon securing OBJECTIVE ORE, position your PLT vicinity of BC 2203, orient south to BC 2204.
e. Do not bypass any enemy resistance.

(4) COORDINATING INSTRUCTIONS:

a. Report all enemy vehicle and aircraft. Do not forget to send reports on all contacts and follow-up with spot reports.
b. MOPP level 0 - chemicals have not been used, not expected.
c. Be prepared to stop the enemy counterattack on OBJECTIVE ORE.
d. Report all friendly graphics.

**SERVICE SUPPORT:**

a. Class I, III, and V on call thru First Sergeant.
b. Report all maintenance/logistics status on company commander (CO) radio net.
c. Report loss of vehicle on CO radio net.
d. During consolidation, immediately send me a PLT ammo status report and a platoon situation report.

**COMMAND AND SIGNAL:**

A. COMMAND:

1. The succession of command is executive officer (XO), 1st, 2nd, and 3rd PLT leaders.
2. The CO will be with 2nd PLT initially.
3. The XO will be with 3rd PLT initially.

B. SIGNAL:

1. 1st PLT call sign is Red 1.
2. 2nd PLT call sign is White 1.
3. 3rd PLT call sign is Green 1.

## TACTICAL MISSION ALPHA - OFFENSIVE MISSION

## FRAGMENTARY ORDERS

<u>Frago 1</u>: (After consolidation of forces is completed on OBJECTIVE ORE - i.e., company commander (CO) has received a complete situation report (SITREP) and logistics report (LOGREP))

CO: "Red 1. This is Black 6. Over."

"Continue to occupy hasty defensive positions."

- BREAK -

"Move one section at a time to CP 8 (ES599919) to resupply."

- BREAK -

"Notify me when your status is REDCON 1. Do not withdraw from your current defensive positions unless specifically ordered. Over."

## TACTICAL MISSION ALPHA - OFFENSIVE MISSION

### FRAGMENTARY ORDERS

<u>Frago 2</u>: {After resupply is complete and REDCON 1 status is reported to the CO.}

CO: "Red 1. This is Black 6. Over."

if IVIS: "Change of mission - Graphics sent over IVIS - Acknowledge receipt. Over."

if baseline: "Change of mission - Prepare to copy and acknowledge. Over."

"Situation: <u>Enemy</u> has withdrawn to the south to establish hasty defensive positions along the ES 86 (E-W) grid line. (BREAK)"

"<u>Friendly</u> task force will continue to attack to the south to secure OBJECTIVES DIAMOND, ONYX, and RUBY. (BREAK)"

"Mission: Team A will attack on order along AXIS SHARP to secure OBJECTIVE RUBY. AXIS SHARP is defined by 3 checkpoints. These checkpoints, in sequence, follow: (BREAK)

"CP12 at ES614894. CP14 at ES614876. CP15 at ES631860. The objective is the hilltop at ES634853. How copy? Over."

"Red 1. Frago continues.
Concept: <u>Maneuver</u>. The Company will attack in travelling overwatch in a company wedge. Red - center, Green - right, and White - left. The company will report CP12. Then, Upon arrival at CP 14, Green and White will occupy overwatch positions and orient on OBJECTIVE RUBY. Red, on order, will assault, to CP 15. Be prepared to sweep through the OBJECTIVE to CP 18 (ES634853). 2nd and 3rd platoons will assault OBJECTIVE RUBY on order. (BREAK)"

"<u>Fires</u>. Artillery for Team A is on request only." (BREAK)

"<u>Specific Instructions</u>. 1st platoon, upon securing OBJECTIVE RUBY, will orient toward TRP 108 (ES616836). Over."

## TACTICAL MISSION ALPHA - OFFENSIVE MISSION

### OPFOR VEHICLE PLACEMENT

| ID | Type | # | Az | Start | Move to | ER |
|---|---|---|---|---|---|---|
| ----- LD COPPER | | | | | | |
| 1 | OP/PC | 1 | 0600 | ES605954 | ES609946 | 250m |
| 2 | GT/PC | 1 | 5600 | ES610949 | Stat | N/A |
| 3 | GT/PC | 1 | 5600 | ES61059490 | Stat | N/A |
| ----- PL TIN | | | | | | |
| 4 | OP/T72 | 1 | 6400 | ES606934 | ES604950 | 500m |
| ----- PL BRASS | | | | | | |
| 5 | GT/T72 | 1 | 0800 | ES60459135 | Stat | N/A |
| 6 | GT/T72 | 1 | 5600 | ES60509130 | Stat | N/A |
| ----- OBJ ORE | | | | | | |
| ----- Initial Placement Above ----- | | | | | | |
| 7 | OP/PC | 1 | 0600 | ES617905 | ES610912 | 250m |
| 8 | OP/PC | 1 | 6400 | ES606900 | ES609914 | 200m |
| ----- SUPPLY | | | | | | |
| 9 | OP/PC | 3 | 6400 | ES615886 | ES620886 | 250m |
| ----- PL OPAL | | | | | | |
| 10 | GT/T72 | 1 | 6000 | ES626865 | Stat | N/A |
| 11 | GT/PC | 1 | 6000 | ES633860 | Stat | N/A |
| 12 | GT/PC | 1 | 6000 | ES63358600 | Stat | N/A |
| 13 | GT/TOC | 1 | 6400 | ES636852 | Stat | N/A |
| ----- OBJ RUBY | | | | | | |

Fuel & Ammo Trucks for Frago #1: ES598920 & ES599919.

### ENEMY ARTILLERY PLACEMENT

----- LD COPPER

1. ES605950

----- PL TIN

2. ES606930

----- PL BRASS

3. ES603918

----- OBJ ORE

4. ES610908
5. ES601905
6. ES613903

----- SUPPLY

7. ES612890

----- PL OPAL

8. ES620872
9. ES638858
10. ES636849

----- OBJ RUBY

**TACTICAL MISSION ALPHA - OFFENSIVE MISSION**

**PREPLANNED FRIENDLY ARTILLERY**

(On Request Only)

1. CP 1 - ES610940
2. BC 2209 - ES615940
3. BC 2206 - ES598927
4. CP 6 - ES603923
5. CP 10 - ES607924
6. CP 8 - ES598920
7. BC 2203 - ES602912
8. CP 4 - ES607913
9. CP 5 - ES611914
10. CP 3 - ES598908
11. BC 2201 - ES596912
12. TRP 103 - ES612880
13. TRP 104 - ES619901
14. TRP 105 - ES601888

**MISSION EVENT SUMMARY**

| Segment # | Event Description |
|---|---|
| 1 | AA -> AP |
| 2 | AP -> PL TIN (CP 1) |
| 3 | PL TIN -> PL BRASS (CP 6) |
| 4 | PL BRASS -> OBJ ORE (CP 4) |
| 5 | OBJ -> REFUEL/REAMMO (CP 9)<br>Section 1 |
| 6 | OBJ -> REFUEL/REAMMO (CP 9)<br>Section 2 |
| 7 | OBJ (Receive FRAGO) -> CP 12<br>FRAGO Order - First Segment<br>Movement to Contact |
| 8 | CP 12 -> PL OPAL (CP 14)<br>FRAGO Order - Second Segment<br>Movement to Contact |
| 9 | PL OPAL -> CP 15<br>Frago Order - Third Segment<br>Hasty Attack/Defense |
| 10 | CP 15 -> OBBJ RUBY (CP 18)<br>FRAGO Order - FInal Segment<br>Hasty Attack/Consolidation |

**TACTICAL MISSION ALPHA - OPFFENSIVE MISSION**

**SPECIAL ADMINISTRATION ORDERS**

1. Stop and report all graphic control points to the company commander (CO). Graphic control points include CPs, LD, PL, AP, RP, OBJ, etc. Include your current UTM 6-digit <u>or higher</u> grid coordinate with these reports.
2. Maintain appropriate vehicle speeds. Do not travel faster than actual terrain would allow.
3. Reinitialization - Report to the CO. Call if any equipment malfunctions.
4. Report all battlefield activity.
5. Do not leave your tanks without informing the CO.
6. If a platoon tank is disabled, all platoon vehicles must halt. Enemy activity will also be halted.
7. Be careful with the radios. They are very touchy. If your radios fail, contact the CO immediately.
8. No assistance from the research assistant.
9. Use IVIS for all reports, if applicable.
10. PLT radio net is frequency 38.
11. CO radio net is frequency 42.
12. Reconstitution will be used to simulate refueling and ammo resupply. Park between the ammo and fuel supply vehicles and report.
13. CO call sign is "Black 6."
14. Remember: Light blue water is fordable in SIMNET. Dark blue water is not.
15. You are allowed a maximum of 3 hours to complete this mission.

# Appendix B

## Defensive Combat Mission Materials

## TACTICAL MISSION BRAVO - DEFENSIVE MISSION

## OPERATIONS ORDER

**ORIENTATION:** You are 1/A/1-14 Armor (AR) located in ASSEMBLY AREA ROBIN at ES602860.

**SITUATION:**

A. ENEMY: We can expect elements of the 143rd Motorized Rifle Division (MRD) to attack our defensive positions with a reinforced motorized rifle battalion (MRB). The enemy is trying to expand their bridgehead on the Ohio River. This MRB is expected to have two motorized rifle companies (MRCs) leading, and one MRC following. The S-2 indicates that the MRB is at 75 percent strength and is equipped with T-62s and BMPs. The enemy is expected to move along the high speed avenue of approach -- the road which runs southwest through our battalion sector.

B. FRIENDLY: (We are A/1-14 AR).

(1) Task Force (TF) 1-14 defends in sector not later than ________. On order, counterattack to complete destruction of the enemy.

(2) 1-14 scouts are located to the front, just forward of the forward edge of the battle area (FEBA), conducting a screening mission.

(3) Team Charlie (C) is defending battle position (BP) 62 on our right flank.

(4) TF 2-87 is defending in sector on our left flank.

(5) Reserve. D Co. is the TF Reserve and is located to our rear.

(6) 1-79 Field Artillery (FA) is in direct support.

C. ATTACHMENTS/DETACHMENTS: None

## TACTICAL MISSION BRAVO - DEFENSIVE MISSION

**MISSION:** A Co/1-14 AR defends BP 75 (ES580945). Initially, in a counter reconaissance role, I want 1st Platoon to move to, and defend from, BP 25A (ES592966). On order, 1st Platoon will displace to, and defend, BP 75A (ES580945). On order, Alpha (A) Co. will displace to BP 17A. On order, A Co. will counterattack to complete enemy destruction.

**EXECUTION:**

A. COMMANDER'S INTENT:

Commander's Intent: Initially, 1st PLT occupy BP25A in a counter reconnaissance role. 1st PLT is to prevent reconnaisance of our primary BP and to knock out reconnaisance elements and to make the enemy deploy and slow him down. My intent is to hold our defensive positions by destroying all enemy in our sector. If necessary, we will displace to BP 17, but only to prepare for a counterattack to hold our positions at all cost.

B. CONCEPT OF THE OPERATION:

(1) Maneuver: We will move out of AA ROBIN in column formation. Order of March: 1st PLT, commanding officer (CO), 2nd PLT, executive officer (XO), 3rd PLT, headquarters (HQ). Move along Route Owl to release point (RP 8). Cross river at fording site located at checkpoint (CP) 5. Road march speed is 20 kmh. Report start point (SP), RP, and all other control measures. Enter BP from rear. 1st PLT move to BP25A. 2nd and 3rd PLTs occupy BP 75B & 75C, respectively. Orient on engagement area. Engage targets forward of engagement area (EA) EAGLE with indirect fire only. Engage targets inside EA EAGLE with direct fire only. The trigger point will be when a PLT size enters EA EAGLE. Disengage only on order. Break point criterion is when a PLT size element has breached the minefield. When I give the order to disengage, move in platoon wedge formation to the next BP. On order, I will issue a fragmentary order (FRAGO) to counterattack.

(2) Fires: 1st Platoon has priority of fires within the team. No preplanned fires. Send calls for fire through me.

(3) Obstacles: Engineer support has already completed all obstacles (see overlay).

(4) Specific instructions: 1st Platoon occupy BP 25A. 2nd and 3rd PLTs occupy BP 75. Orient on road in EA EAGLE. At BP 25, I expect you to engage enemy recon element. On order, you will displace to BP 75A. I do not want you decisively engaged at BP 25.

(5) Coordinating Instructions: PIR - Report all enemy vehicles, aircraft. Don't forget to send me reports on all contact and follow up with a spot report. MOPP Level 0 - Chemicals have not been used and are not expected.

**SERVICE SUPPORT:** Report all maintenance/logistics status on CO net. Report loss of vehicle on CO net. During consolidation, immediately send me a platoon ammo status and a platoon situation report.

**COMMAND AND SIGNAL:**

A. COMMAND:
(1) I will be with the 2nd Platoon initially.
(2) XO will be with the 3rd Platoon initially.
(3) Succession will be XO, 1st, 2nd, 3rd platoon leaders.

B. SIGNAL:
(1) 1st Platoon call sign is Red 1.
(2) 2nd Platoon call sign is White 1.
(3) 3rd Platoon call sign is Green 1.

## TACTICAL MISSION BRAVO - DEFENSIVE MISSION

### FRAGMENTARY ORDERS

<u>Frago 1</u>: {After at least 3 enemy kills at BP 25A <u>or</u> maximum of 2 rounds fired per tank is reached by platoon.}

CO: "Red 1. This is Black 6. Over."

"Displace immediately to BP 75A. Over."

<u>Frago 2</u>: {After platoon reaches breakpoint at EA EAGLE.}

CO: "Red 1. This is Black 6. Over."

"Displace immediately to BP 17A. Orient between TRP 030 and 040."

<u>Frago 3</u>: {After platoon has occupied BP 17A for 5 minutes.}

CO: "Red 1. This is Black 6. Over."

if IVIS: "Change of mission - graphics sent over IVIS acknowledge receipt. Over."

if baseline: "Change of mission - prepare to copy and acknowledge. Over."

"<u>Enemy</u>. An enemy company has broken through TF 3-57 defenses and is moving southwest (SW) along the highway vicinity of ES620915. It appears they will attempt to secure the river crossing at ES 595879."

\- BREAK -

"<u>Mission</u>. Establish a defensive position at BP 53 (ES575883) to destroy elements attacking south. Move along Route Owl. Report SP at ES576907 and RP at ES571889."

\- BREAK -

"Report when you are ready to move out. Report when in [illegible] battle position. Over."

## TACTICAL MISSION BRAVO - DEFENSIVE MISSION

### OPFOR VEHICLE PLACEMENT

| ID | Type | # | Az | Start | Move to | ER | |
|---|---|---|---|---|---|---|---|
| | | | | | | | RP 8 |
| 1 | BMP | Plt | 4000 | ES615986 | ES600970 | CS/500m | |
| | | | | | | | BP 25A |
| 2 | BMP | Plt | 4000 | ES630980 | ES590950 | CS/1000m | |
| 3 | T72 | 1 | 4000 | ES30980 | ES594953 | CS/1000m | |
| 4 | T72 | Plt | 3200 | ES586960 | ES585947 | CS/500m | |
| | | | | | | | BP 75A |
| 5 | T72 | Plt | 4000 | ES617948 | ES586931 | CS/500m | |
| 6 | BMP | Plt | 4400 | ES598930 | ES584928 | CS/500m | |
| | | | | | | | BP 17A |
| 7 | BMP | Plt | 4400 | ES584900 | ES576898 | No fire | |
| | | | | | | | RP |
| 8 | BMP | Plt | 3200 | ES600891 | ES595881 | CS/1000m | |
| 9 | T72 | Plt | 4000 | ES600900 | ES584885 | CS/700m | |
| | | | | | | | BP 53 |

Note: Two M1 Plts follows friendly forces to BP 75 and BP 17 (CS/1400m).

### ENEMY ARTILLERY PLACEMENT

---------------------------------------- BP 25A

1. ES606974
2. ES597960

---------------------------------------- Displace to BP 75A

3. ES582954
4. ES586946
5. ES586950

---------------------------------------- Displace to BP 17A

6. ES588929
7. ES590932

---------------------------------------- Displace to BP 53

8. ES577910

---------------------------------------- Arrive at RP

9. ES575892
10. ES582883

---------------------------------------- BP 53

## TACTICAL MISSION BRAVO - DEFENSIVE MISSION

## MISSION EVENT SUMMARY

| Segment # | Event Description |
|---|---|
| 1 | AA -> River Crossing (CP 5)<br>Tactical Road March |
| 2 | CP 5 -> PL STOP<br>Tactical Road March |
| 3 | PL STOP -> RP 8<br>Tactical Road March |
| 4 | RP 8 -> BP 25A<br>Occupy Original Battle Position<br>Hasty Defense |
| 5 | BP 25A -> BP 75A<br>FRAGO 1: Displace to BP 75A<br>Hasty Withdrawal/Defense |
| 6 | BP 75A -> BP 17A<br>FRAGO 2: Displace to BP 17A<br>Hasty Withdrawal/Defense |
| 7 | BP 17A -> Receive FRAGO<br>FRAGO 3: Displace to BP 53<br>Hasty Defense/Change of Mission |
| 8 | BP17A -> SP<br>FRAGO 3: Displace to BP 53<br>Hasty Withdrawal |
| 9 | SP -> RP<br>Frago 3: Displace to BP 53<br>Hasty Withdrawal |
| 10 | RP -> BP 53<br>Frago 3: Displace to BP 53<br>Consolidation/Hasty Defense |

**TACTICAL MISSION BRAVO - DEFENSIVE MISSION**

**SPECIAL ADMINISTRATION ORDERS**

1. Stop and report all graphic control points to the company commander (CO). Graphic control points include CPs, LD, PL, AP, RP, OBJ, etc. Include your current UTM 6-digit or higher grid coordinate with these reports.

2. Maintain appropriate vehicle speeds. Do not travel faster than actual terrain would allow.

3. Reinitialization - Report to the CO. Call if any equipment malfunctions.

4. Report all battlefield activity.

5. Do not leave your tanks without informing the CO.

6. If a platoon tank is disabled, all platoon vehicles must halt. Enemy activity will also be halted.

7. Be careful with the radios. They are very touchy. If your radios fail, contact the CO immediately.

8. No assistance from the research assistant.

9. Use IVIS for all reports, if applicable.

10. PLT radio net is frequency 38.

11. CO radio net is frequency 42.

12. Reconstitution will be used to simulate refueling and ammo resupply. Park between the ammo and fuel supply vehicles and report.

13. CO call sign is "Black 6."

14. Remember: Light blue water is fordable in SIMNET.
    Dark blue water is not.

15. You are allowed a maximum of 3 hours to complete this mission.

## Appendix C

## Criterion-Oriented Scoring Strategies Used for Each of the Crew $C^3$ Tasks

CRITERION-ORIENTED SCORING STRATEGY
Crew $C^3$ Documentation

# I. OTHER LOCATION REPORTS

## A. CONTACT REPORTS

1. Six reports prompted. Each report worth up to five points each. Total of 30 points possible.

2. Scoring Strategy, Per Report:

   SENT --3 points if CONTACT report sent
   WHAT --1 point if CONTACT "what" correct
   WHERE--1 point if CONTACT "where" correct

CONTACT REPORT SCORE = SENT + WHAT + WHERE

## B. SPOT REPORTS

1. Six reports prompted. Each report worth up to twelve points each. Total of 72 points possible.

2. Scoring Stragegy, Per Report:

   SENT --2 points if SPOT REPORT sent
   WHAT --1 point if SPOT REPORT "what" correct
   COUNT--1 point if SPOT REPORT "count" correct
   TIME --4 points if SPOT REPORT sent within 30 seconds of engagement event end
   --3 points if SPOT REPORT sent within 90 seconds but greater than 30 seconds of engagement event end
   --1 point if SPOT REPORT sent within 300 seconds but greater than 90 seconds of engagement event end
   GRID --4 points if SPOT REPORT grid within 200 meters of actual target grid location
   --3 points if SPOT REPORT grid within 500 meters but greater than 200 meters of actual target grid location
   --1 point if SPOT REPORT grid within 1000 meters but greater than 500 meters of actual target grid

SPOT REPORT SCORE = SENT + WHAT + COUNT + TIME + GRID

C. SHELL REPORTS

1. Eight reports prompted. Each report worth up to 10 points each. Total of 80 points possible.

2. Scoring Strategy, Per Report:

SENT --2 points if SHELL REPORT sent
TIME --4 points if SHELL REPORT sent within 30 seconds of initial shell impact
--3 points if SHELL REPORT sent in less than 90 seconds but greater than 30 seconds of initial shell impact
--1 point if SHELL REPORT sent in less than 300 seconds but greater than 90 seconds of initial shell impact
GRID --4 points if SHELL REPORT grid within 200 meters of actual shell impact grid location
--3 points if SHELL REPORT grid within 500 but greater than 200 meters of actual shell impact grid location
--1 point if SHELL REPORT grid within 1000 meters but greater than 500 meters of actual shell impact grid location

SHELL REPORT SCORE = SENT + TIME + GRID

D. OTHER LOCATION REPORTS COMPOSITE SCORE

1. Based on the sum of the standardized scores for CONTACT, SPOT, and SHELL REPORTS. Unit weighting scheme used.

2. These three reports (CONTACT, SPOT, and SHELL REPORTS) are combined to form one score based on their similar command and control function -- to report battlefield activities.

OTHER LOCATION REPORTS COMPOSITE SCORE =
CONTACT REPORT Z SCORE
\+ SPOT REPORT Z SCORE
\+ SHELL REPORT Z SCORE

II. OWN LOCATION REPORTS

A. CHECKPOINT REPORTS

1. Seven checkpoint reports prompted. Each report worth up to 4 points each. Total of 28 points possible.

2. Scoring Strategy, Per Report:

GRID --4 points if CHECKPOINT REPORT grid within 200 meters of actual checkpoint location
--3 points if CHECKPOINT REPORT grid within 500 meters but greater than 200 meters of actual checkpoint location
--1 point if CHECKPOINT REPORT grid within 1000 meters but greater than 500 meters of actual checkpoint location

CHECKPOINT REPORT SCORE = GRID

B. OWNLOC REPORTS

1. Four own location reports prompted. Each report worth up to 8 points each. Total of 32 points possible.

2. Scoring Strategy, Per Report:

GRID --4 points if OWNLOC REPORT grid within 200 meters of actual checkpoint location
--3 points if OWNLOC REPORT grid within 500 meters but greater than 200 meters of actual checkpoint location
--1 point if OWNLOC REPORT grid within 1000 meters but greater than 500 meters of actual checkpoint location

TIME --4 points if OWNLOC REPORT sent within 30 seconds of initial shell impact
--3 points if OWNLOC REPORT sent in less than 90 seconds but greater than 30 seconds of initial shell impact
--1 point if OWNLOC REPORT sent in less than 300 seconds but greater than 90 seconds of initial shell impact

OWNLOC REPORT SCORE = GRID + TIME

C. OWN LOCATION REPORTS COMPOSITE SCORE

1. Based on the sum of the standardized scores for CHECKPOINT and OWNLOC REPORTS. Unit weighting scheme used.

2. These two reports (CHECKPOINT and OWNLOC REPORTS) are combined to form one composite score based on their similar command and control function -- to report own vehicle location.

OWN LOCATION REPORTS COMPOSITE SCORE =
CHECKPOINT REPORT Z SCORE
\+ OWNLOC REPORT Z SCORE

## III. CALLS FOR FIRE

A. Three Calls For Fire Prompted. Each Call For Fire worth up to 20 points. Total of 60 points possible.

B. Scoring Strategy, Per Call For Fire:

TIME --4 points if target effect reached within 90 seconds of target acquisition
--3 points if target effect reached in less than 300 seconds but greater than 90 seconds of target acquisiton
--1 point if target effect reached in less than 600 seconds but greater than 300 seconds of target acquisition

GRID --4 points if initial Call For Fire grid within 200 meters of actual target grid location
--3 points if initial Call For Fire grid less than 500 meters but greater than 200 meters from actual target grid location
--1 point if initial Call For Fire grid less than 1000 meters but greater than 500 meters from actual target grid location

ADJS --4 points if target effect reached within one call for fire mission
--3 points if target effect reached within 3 but greater than one call for fire missions
--1 point if target effect reached within 6 but greater than 3 call for fire missions

STAT --8 points if target effect reached
--0 points ONLY if kill self with call for fire mission (total score is 0)
--1 point ONLY if no target effect is reached

target effect occurs when indirect fire impacts within 200 meters of actual target grid location

CALL FOR FIRE SCORE
-- if target effect reached, TIME + GRID + ADJS + STAT
-- if target effect not reached, STAT or 0

IV. BYPASS OBSTACLES SCORE

A. Two bypass tasks prompted. Each bypass worth up to 10 points each. Total of 20 points possible.

B. Scoring Strategy, Per Bypass:

TIME --4 points if time to bypass less than road march time (NBC bypass completed within 1200 seconds, MINE bypass completed within 900 seconds)
--2 points if time to bypass less than twice road march time (NBC bypass completed within 2400 seconds, MINE bypass within 1800 seconds)
--1 point if time to bypass greater than twice road march time (NBC bypass completed in greater than 2400 seconds, MINE bypass completed in greater than 1800 seconds)

STAT --6 points if bypass successful (crew did not enter bypass area, i.e., NBC or MINE)
--0 points ONLY if bypass not successful (crew entered bypass area, i.e., NBC or MINE)

BYPASS OBSTACLES SCORE =
if bypass successful, TIME+STAT
if bypass not successful, STAT or 0

V. FRAGMENTARY ORDERS SCORE

A. Two FRAGMENTARY ORDERS presented. Each order worth up to 12 points each. Total of 24 points possible.

B. Scoring Strategy, Per ORDER:

TIME --4 points if frago executed within road march time (1200 seconds for NBC FRAGO, 600 seconds for Battle Position FRAGO)
--2 points if frago executed within twice road march time (2400 seconds for NBC FRAGO, 1200 seconds for battle position FRAGO)
--1 point if frago executed in greater than twice road march time (more than 2400 seconds for NBC FRAGO, more than 1200 seconds for battle position FRAGO)

PLAN --2 points if plan time less than one standard deviation above mean
--1 point if plan time within one standard deviation from mean

STAT (for NBC FRAGO)
--6 points if NBC FRAGO successful (crew did not enter NBC area)
--0 points ONLY if NBC FRAGO not successful (crew entered NBC area)

STAT (for Battle Position FRAGO)
--4 points if battle position location within 200 meters of actual battle position location assigned
--2 points if battle position location within 500 meters but greater than 200 meters from actual battle position location assigned
--2 points if battle position orientation of main gun within assigned sector
--0 points only if battle position location assigned greater than 500 meters of assigned battle position location and main gun orientation not within assigned sector

FRAGMENTARY ORDER SCORE =
if bypass successful, TIME + PLAN + STAT
if bypass not successful, STAT or 0

## Appendix D

## Criterion-Oriented Scoring Strategies Used for Each of the Platoon $C^3$ Tasks

CRITERION-ORIENTED SCORING STRATEGY
Platoon $C^3$ Documentation

# I. OTHER LOCATION REPORTS

## A. CONTACT REPORTS

1. Ten reports prompted. Each report worth up to five points each. Total of 50 points possible.

2. Scoring Strategy, Per Report:

   SENT --5 points if CONTACT report sent

CONTACT REPORT SCORE = SENT

## B. SPOT REPORTS

1. Ten reports prompted. Each report worth up to eight points each. Total of 80 points possible.

2. Scoring Stragegy, Per Report:

   TIME --4 points if SPOT REPORT sent within 30 seconds of engagement event end
   --3 points if SPOT REPORT sent within 90 seconds but greater than 30 seconds of engagement event end
   --1 point if SPOT REPORT sent within 300 seconds but greater than 90 seconds of engagement event end
   GRID --4 points if SPOT REPORT grid within 200 meters of actual target grid location
   --3 points if SPOT REPORT grid within 500 meters but greater than 200 meters of actual target grid location
   --1 point if SPOT REPORT grid within 1000 meters but greater than 500 meters of actual target grid

SPOT REPORT SCORE = TIME + GRID

C. SHELL REPORTS

1. Ten reports prompted. Each report worth up to eight points each. Total of 80 points possible.

2. Scoring Strategy, Per Report:

TIME --4 points if SHELL REPORT sent within 30 seconds of initial shell impact
--3 points if SHELL REPORT sent in less than 90 seconds but greater than 30 seconds of initial shell impact
--1 point if SHELL REPORT sent in less than 300 seconds but greater than 90 seconds of initial shell impact

GRID --4 points if SHELL REPORT grid within 200 meters of actual shell impact grid location
--3 points if SHELL REPORT grid within 500 but greater than 200 meters of actual shell impact grid location
--1 point if SHELL REPORT grid within 1000 meters but greater than 500 meters of actual shell impact grid location

SHELL REPORT SCORE = TIME + GRID

D. OTHER LOCATION REPORTS COMPOSITE SCORE

1. Based on the sum of the standarized scores for CONTACT, SPOT, and SHELL REPORTS. Unit weighting sheme used.

2. These three reports (CONTACT, SPOT, and SHELL REPORTS) are combined to form one score based on their similar command and control function -- to report battlefield activities.

OTHER LOCATION REPORTS COMPOSITE SCORE =
CONTACT REPORT Z SCORE
\+ SPOT REPORT Z SCORE
\+ SHELL REPORT Z SCORE

## II. OWN LOCATION REPORTS

1. Seven checkpoint reports and four own location reports prompted. Each report worth up to eight points each. Total of 88 points possible.

2. Scoring Strategy, Per Report:

   GRID --4 points if report grid within 200 meters of actual checkpoint location
   --3 points if report grid within 500 meters but greater than 200 meters of actual checkpoint location
   --1 point if report grid within 1000 meters but greater than 500 meters of actual checkpoint location

   TIME --4 points if report sent within 30 seconds of initial shell impact
   --3 points if report sent in less than 90 seconds but greater than 30 seconds of initial shell impact
   --1 point if report sent in less than 300 seconds but greater than 90 seconds of initial shell impact

OWNLOC REPORT SCORE = GRID + TIME

III. FRAGMENTARY ORDERS SCORE

A. Two FRAGMENTARY ORDERS presented. Each order worth up to 12 points each. Total of 24 points possible.

Note: For the defensive mission, three FRAGOs were presented. Points assignments, however, were multiplied by .66, however, to assure that the total points possible remained 24.

B. Scoring Strategy, Per ORDER:

TIME --4 points if frago executed within road march time (1200 seconds for NBC FRAGO, 600 seconds for Battle Position FRAGO)
--2 points if frago executed within twice road march time (2400 seconds for NBC FRAGO, 1200 seconds for battle position FRAGO)
--1 point if frago executed in greater than twice road march time (more than 2400 seconds for NBC FRAGO, more than 1200 seconds for battle position FRAGO)
PLAN --2 points if plan time less than one standard deviation above mean
--1 point if plan time within one standard deviation from mean
STAT --6 points if FRAGO successfully executed
--0 points ONLY if FRAGO not successful

FRAGMENTARY ORDER SCORE =
if bypass successful, TIME + PLAN + STAT
if bypass not successful, STAT or 0

# Appendix E

## Normative-Oriented Scoring Strategies Used for Each of the Crew $C^3$ Tasks

NORMATIVE-ORIENTED SCORING STRATEGY
Crew $C^3$ Documentation

I. CONTACT REPORTS: ZCONREP

Z score for number of reports sent, accuracy of report "what" component measure, and accuracy of report "where" component measure.

II. SPOT REPORTS: ZSPOTREP

Sum of Z scores for number of reports sent measure, accuracy of report "what" measure, accuracy of report "count" measure, time to send report measure, and accuracy of report grid measure.

III. SHELL REPORTS: ZSHELLREP

Sum of Z scores for number of reports sent measure, time to send report measure, and accuracy of report grid measure.

IV. OTHER LOCATION REPORTS: ZOTHERREP

Sum of normative scores for CONTACT, SPOT, and SHELL reports.

V. CHECKPOINT REPORTS: ZCPREP

Z score for accuracy of report measure.

VI. OWN LOCATION REPORTS: ZOWNLOC

Sum of Z scores for time to send report and accuracy of report measures.

VII. OWN LOATION REPORTS: ZOWNREP

Sum of normative scores for CHECKPOINT and OWN LOCATION reports.

VIII. CFF Requests: ZCFF

Sum of Z scores for CFF success, time, accuracy, and number of adjustments required measures.

IX. Obstacle Bypasses: ZBYPASS

Sum of Z scores for execution time and success measures.

X. Change of Mission Orders: ZFRAGO

Sum of Z scores for plan time, execution time, and success measures.

XI. Exercise Time: ZTIME

Sum of Z scores for exercise plan and execution time measures.

Note: Time and accuracy measure Z score values reversed (i.e., negative values made positive--positive values made negative).

Appendix F

Normative-Oriented Composite Scoring Strategies
For Platoon Performance Measures

NORMATIVE-ORIENTED SCORING STRATEGIES
Platoon C3 Documentation

I CONTACT Reports: ZCONREP

Z score for number of reports sent.

II. SPOT Reports: ZSPOTREP

Sum of Z scores for report accuracy, report time, and number of reports sent measures.

III. SHELL Reports: ZSHELLREP

Sum of Z scores for report accuracy, report time, and number of reports sent measures.

IV. Other Location Reports: ZOTHERREP

Sum of normative-oriented scores for number of CONTACT reports sent, ZSPOTREP, and ZSHELLREP measures.

V. Own Location Reports: ZOWNREP

Sum of Z scores for report accuracy and report time measures.

VI. Mission Time: ZMSNTIME

Z score for mission execution time measure.

VII. Mission Done: ZMSNDONE

Z score for percent of mission completed measure.

VIII. Change of Mission Orders: ZFRAGO

Sum of Z scores for FRAGO success, plan time, and execution time measures.

Note: Time and accuracy measure Z values reversed (i.e., negative values made positive--positive values made negative).

Appendix G

Additional Group Equivalence Analyses

Table G-1

Soldier Data by Tank Position

| Soldier Measure | | Overall | Tank Position | | | | |
|---|---|---|---|---|---|---|---|
| | | | PL | PS | TC | DV | GN |
| Job | M | 24 | 7 | 23 | 39 | 21 | 23 |
| Experience | SD | 25 | 7 | 27 | 22 | 18 | 31 |
| (Months) | N | 144 | 12 | 12 | 24 | 48 | 48 |
| Armor | M | 68 | 9 | 141 | 109 | 47 | 65 |
| Experience | SD | 53 | 8 | 66 | 40 | 36 | 43 |
| (Months) | N | 144 | 12 | 12 | 24 | 48 | 48 |
| Last | M | 72 | 46 | 117 | 109 | 45 | 76 |
| Exercise | SD | 87 | 49 | 126 | 111 | 60 | 85 |
| (Weeks) | N | 144 | 12 | 12 | 24 | 48 | 48 |
| NTC | M | .69 | 0 | 1.18 | .86 | .63 | .74 |
| Rotations | SD | 1.19 | 0 | 1.83 | 1.08 | 1.10 | 1.24 |
| | N | 1.40 | 12 | 11 | 22 | 48 | 47 |
| SIMNET | M | 22 | 19 | 20 | 24 | 19 | 23 |
| Experience | SD | 36 | 29 | 29 | 46 | 29 | 41 |
| (Hours) | N | 144 | 12 | 12 | 24 | 48 | 48 |
| UCOFT | M | 69 | 24 | 60 | 207 | 25 | 58 |
| Experience | SD | 225 | 35 | 74 | 486 | 39 | 148 |
| (Hours) | N | 143 | 12 | 11 | 24 | 48 | 48 |
| ASVAB CO | M | 109 | * | 107 | 111 | 108 | 108 |
| Score | SD | 11 | * | 10 | 12 | 12 | 12 |
| | N | 119 | * | 10 | 22 | 42 | 45 |
| ASVAB GT | M | 106 | * | 102 | 107 | 106 | 106 |
| Score | SD | 13 | * | 10 | 13 | 14 | 13 |
| | N | 123 | * | 11 | 24 | 42 | 46 |
| Land | M | 10 | 15 | 11 | 11 | 9 | 10 |
| Navigation | SD | 4 | 2 | 4 | 5 | 5 | 4 |
| Test | N | 144 | 12 | 12 | 24 | 24 | 48 |
| SIMNET | M | 15 | 15 | 15 | 15 | | |
| Knowledge | SD | 1 | 1 | 1 | 1 | * | * |
| Test | N | 48 | 12 | 12 | 24 | | |

* drivers and gunners did not complete the SIMNET Knowledge Test

Table G-2

Omnibus MANOVA for Selected Soldier Data

Interaction: Test Condition by Tank Position

| Test | Value | Approx F | Hyp df | Em df | p |
|---|---|---|---|---|---|
| Pillais V | .18658 | .88070 | 28 | 504.00 | .645 |
| Hotellings | .20528 | .89078 | 28 | 406.00 | .630 |
| Wilks | .82236 | .88571 | 28 | 444.91 | .637 |
| Roys | .11774 | | | | |

Main Effect: Test Condition

| Test | Value | Approx F | Hyp df | Em df | p |
|---|---|---|---|---|---|
| Pillais V | .05793 | 1.08059 | 7 | 123 | .380 |
| Hotellings | .06150 | 1.08059 | 7 | 123 | .380 |
| Wilks | .94207 | 1.08059 | 7 | 123 | .380 |
| Roys | .05793 | | | | |

Main Effect: Tank Position

| Test | Value | Approx F | Hyp df | Em df | p |
|---|---|---|---|---|---|
| Pillais V | .63932 | 3.42422 | 28 | 504.00 | <.001* |
| Hotellings | 1.00114 | 4.34423 | 28 | 486.00 | <.001* |
| Wilks | .45492 | 3.87943 | 28 | 486.00 | <.001* |
| Roys | .43709 | | | | |

* statistically significant ($p<.05$)
Note: Selected soldier data includes job experience, Armor experience, time since last field exercise, NTC rotation, SIMNET experience, UCOFT experience, and LNST score. Test groups include IVIS and No IVIS. Tank positions include platoon leader, platoon sergeant, tank commander, driver, and gunner.

Table G-3

Univariate ANOVAs for the Tank Position Main Effect

| Soldier Measure | Treatment Mean Square | Error Mean Square | F Value | p |
|---|---|---|---|---|
| JOB Exp | 2357.27 | 580.31 | 4.06 | .004* |
| ARMOR Exp | 41504.05 | 1663.36 | 24.95 | <.001* |
| Last Exercise | 25013.63 | 7155.82 | 3.50 | .009* |
| NTC Rotations | 2.34 | 1.38 | 1.70 | .154 |
| SIMNET Exp | 156.32 | 1328.82 | .12 | .976 |
| UCOFT Exp | 145529.79 | 47871.97 | 3.04 | .019* |
| LNST Score | 67.15 | 18.26 | 3.68 | .007* |
| SIMNET Score | .45 | 1.40 | .31 | .735 |

*statistically significant ($p<.05$)

Table G-4

Omnibus MANOVA Tests for Soldier ASVAB Scores: CO & GT

Interaction: Test Condition by Tank Position

| Test | Value | Approx F | Hyp Df | Em Df | p |
|---|---|---|---|---|---|
| Pillais V | .02010 | .37563 | 6 | 222 | .894 |
| Hotellings | .02047 | .37186 | 6 | 218 | .896 |
| Wilks Lamda | .97992 | .37376 | 6 | 220 | .895 |
| Roys GCR | .01899 | | | | |

Main Effect: Test Condition

| Test | Value | Approx F | Hyp Df | Em Df | p |
|---|---|---|---|---|---|
| Pillais V | .03097 | 1.75803 | 2 | 110 | .177 |
| Hotellings | .03196 | 1.75803 | 2 | 110 | .177 |
| Wilks Lamda | .96903 | 1.75803 | 2 | 110 | .177 |
| Roys GCR | .03097 | | | | |

Main Effect: Tank Position

| Test | Value | Approx F | Hyp Df | Em Df | p |
|---|---|---|---|---|---|
| Pillais V | .04521 | .85564 | 6 | 222 | .528 |
| Hotellings | .04645 | .84378 | 6 | 218 | .537 |
| Wilks Lamda | .95521 | .84972 | 6 | 220 | .533 |
| Roys GCR | .03217 | | | | |

Note: Platoon leaders not included in sample as they do not complete the ASVAB.

## Appendix H

## Task Difficulty Questionnaire Ratings

Table H-1

Task Difficulty Questionnaire: IVIS and NO IVIS Means (M) and Standard Deviations (SD) for Each $C^3$ Task

| | | IVIS | | | NO IVIS | | |
|---|---|---|---|---|---|---|---|
| $C^3$ Task | | T1 Tank | T2 Tank | SIM | T1 Tank | T2 Tank | SIM |
| 1. Determining your tank grid location. | M | 4.46 | 3.67 | 1.29 | 3.08 | 3.13 | 3.50 |
| | SD | 1.44 | 1.74 | .62 | 1.70 | 1.23 | 1.54 |
| 2. Determining your tank orientation. | M | 3.33 | 3.17 | 1.38 | 2.71 | 2.67 | 3.20 |
| | SD | 1.52 | 1.40 | .58 | 1.43 | 1.52 | 1.74 |
| 3. Maintaining your tank orientation. | M | 3.71 | 3.58 | 1.50 | 3.38 | 2.71 | 3.45 |
| | SD | 1.52 | 1.66 | .72 | 1.58 | 1.60 | 1.70 |
| 4. Determining the grid location of other objects (e.g., spot reports). | M | 3.96 | 3.75 | 1.58 | 3.50 | 3.00 | 4.00 |
| | SD | 1.43 | 1.82 | .78 | 1.59 | 1.60 | 1.70 |
| 5. Performing Map-Terrain association. | M | 3.17 | 3.50 | 1.92 | 3.67 | 2.67 | 3.90 |
| | SD | 1.61 | 1.50 | .93 | 1.27 | 1.34 | 1.62 |
| 6. Navigating from one point to another. | M | 3.29 | 3.54 | 1.38 | 3.38 | 2.83 | 3.55 |
| | SD | 1.43 | 1.82 | .77 | 1.56 | 1.44 | 1.67 |
| 7. Maintaining platoon formation. | M | 3.54 | 3.50 | 2.33 | 3.25 | 2.79 | 3.15 |
| | SD | 1.29 | 1.40 | 1.40 | 1.62 | 1.53 | 1.41 |
| 8. Reorienting after reacting to enemy fire (e.g., air or artillery strikes). | M | 4.42 | 4.17 | 2.25 | 4.25 | 2.96 | 3.50 |
| | SD | 1.59 | 1.58 | 1.23 | 1.48 | 1.76 | 1.85 |
| 9. Preparing a battlefield report. | M | 4.29 | 4.42 | 1.67 | 4.50 | 3.54 | 3.15 |
| | SD | 1.37 | 1.28 | .76 | 1.14 | 1.44 | 1.50 |
| 10. Sending a battlefield report. | M | 4.13 | 4.00 | 1.75 | 3.92 | 3.25 | 2.85 |
| | SD | 1.42 | 1.50 | .85 | 1.32 | 1.33 | 1.27 |
| 11. Relaying a battlefield report. | M | 4.46 | 4.00 | 1.67 | 3.42 | 3.13 | 2.70 |
| | SD | 1.44 | 1.50 | .82 | 1.41 | 1.15 | 1.26 |
| 12. Receiving a battlefield report. | M | 4.21 | 3.75 | 1.71 | 3.17 | 2.67 | 2.35 |
| | SD | 1.44 | 1.54 | .91 | 1.58 | 1.13 | 1.18 |

Table H-1 (Continued)

Task Difficulty Questionnaire: IVIS and NO IVIS Means (M) and Standard Deviations (SD) for Each $C^3$ Task

| $C^3$ Task | | IVIS T1 Tank | IVIS T2 Tank | IVIS SIM | NO IVIS T1 Tank | NO IVIS T2 Tank | NO IVIS SIM |
|---|---|---|---|---|---|---|---|
| 13. Receiving a FRAGO. | M | 3.96 | 4.33 | 1.63 | 3.08 | 2.46 | 2.20 |
| | SD | 1.57 | 1.61 | .82 | 1.56 | 1.35 | 1.28 |
| 14. Issuing (relaying) a FRAGO. | M | 3.96 | 4.33 | 1.63 | 3.08 | 2.46 | 2.20 |
| | SD | 1.57 | 1.68 | 1.02 | 1.37 | 1.31 | 1.32 |
| 15. Executing a FRAGO. | M | 3.79 | 3.75 | 1.79 | 3.63 | 2.92 | 3.10 |
| | SD | 1.35 | 1.54 | .88 | 1.44 | 1.32 | 1.25 |
| 16. Selecting firing positions. | M | 3.00 | 3.00 | 2.79 | 2.71 | 2.75 | 3.75 |
| | SD | 1.45 | 1.22 | 1.10 | 1.37 | 1.26 | 1.59 |
| 17. Reporting graphic control points (e.g., CPS, LDS, etc). | M | 3.25 | 3.83 | 1.63 | 2.83 | 2.79 | 3.15 |
| | SD | 1.33 | 1.37 | .82 | 1.47 | 1.35 | 1.35 |
| 18. Occupying battle positions. | M | 2.92 | 3.13 | 2.17 | 2.88 | 2.63 | 3.35 |
| | SD | 1.32 | 1.08 | 1.01 | 1.6o | 1.06 | 1.46 |
| 19. Adjusting fires. | M | 4.04 | 4.21 | 1.79 | 3.71 | 3.42 | 4.00 |
| | SD | 1.73 | 1.32 | .78 | 1.43 | 1.47 | 1.41 |
| 20. Consolidating unit after enemy contact. | M | 4.38 | 4.21 | 1.88 | 4.04 | 3.46 | 3.55 |
| | SD | 1.56 | 1.56 | .95 | 1.12 | 1.53 | 1.54 |
| 21. Moving under direct/indirect fires. | M | 4.50 | 4.46 | 2.08 | 4.08 | 3.29 | 3.25 |
| | SD | 1.62 | 1.64 | .97 | 1.59 | 1.40 | 1.41 |
| 22. Conducting displacement at platoon level. | M | 4.05 | 4.04 | 2.13 | 4.33 | 3.17 | 3.70 |
| | SD | 1.35 | 1.43 | 1.12 | 1.47 | 1.37 | 1.46 |
| 23. Controlling platoon fires. | M | 4.33 | 4.25 | 2.71 | 4.42 | 3.38 | 4.00 |
| | SD | 1.79 | 1.62 | 1.20 | 1.38 | 1.47 | 1.52 |

Table H-1 (Continued)

Task Difficulty Questionnaire: IVIS and NO IVIS Means (M) and Standard Deviations (SD) for Each $C^3$ Task

| $C^3$ Task | | IVIS T1 Tank | IVIS T2 Tank | IVIS SIM | NO IVIS T1 Tank | NO IVIS T2 Tank | NO IVIS SIM |
|---|---|---|---|---|---|---|---|
| 24. Controlling | M | 3.96 | 3.92 | 2.13 | 3.79 | 3.13 | 3.40 |
| tactical movement. | SD | 1.60 | 1.41 | .99 | 1.50 | 1.42 | 1.45 |
| 25. Conducting a | M | 3.88 | 3.92 | 2.08 | 3.88 | 3.08 | 3.55 |
| hasty attack. | SD | 1.33 | 1.32 | .83 | 1.65 | 1.41 | 3.55 |
| 26. Conducting a | M | 3.50 | 3.58 | 1.88 | 3.58 | 2.83 | 3.20 |
| movement to contact. | SD | 1.32 | 1.32 | .80 | 1.56 | 1.27 | 1.36 |
| 27. Conducting a | M | 3.29 | 3.50 | 1.96 | 3.71 | 2.96 | 3.50 |
| hasty defense. | SD | 1.33 | 1.41 | .75 | 1.60 | 1.33 | 1.36 |

Note: T1Tank is the pre-training task difficulty assessment. T2Tank is the post-exercises task difficulty assessment. Both tank ratings are estimates of the difficulty of performing each $C^3$ tank in a real tank in the field using conventional tools and procedures. SIM is a post-exercises SIMNET task difficulty assessment. SIM ratings reflect the difficulty, using the tools available in their test condition, that commanders experienced completing each $C^3$ task in SIMNET-D.

Appendix I

IVIS Interface Questionnaire Ratings

Table I-1

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

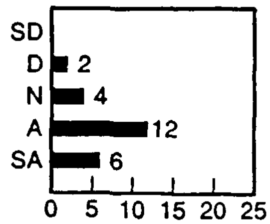
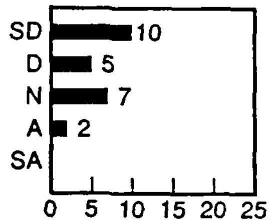
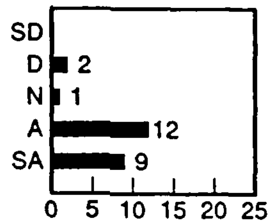
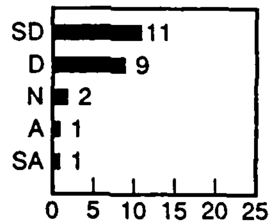
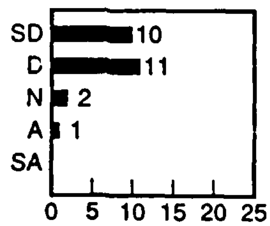
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 1. The location of the commander's IVIS display in the M1 simulator was acceptable. | 3.92 | .88 |  |
| 2. I would have difficulty navigating from one point to another using only the IVIS driver's "steer-to" display. | 2.04 | 1.04 |  |
| 3. When my tank was moving, the IVIS map automatically scrolled at an acceptable rate. | 4.17 | .87 |  |
| 4. The IVIS map at the 1:25,000 scale (about 3km by 3km) is difficult to read. | 1.83 | 1.05 |  |
| 5. The IVIS map at the 1:50,000 scale (about 5km by 5km) is difficult to read. | 1.75 | .79 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

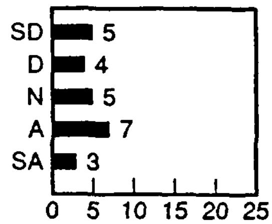
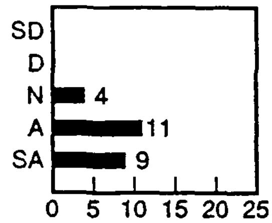
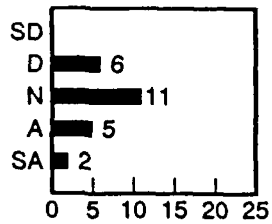
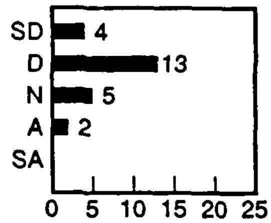
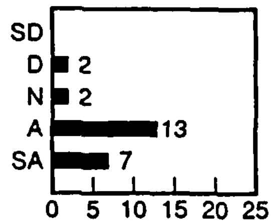
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 6. The IVIS map at the 1:125,000 scale (about 11km by 11km) is difficult to read. | 2.96 | 1.37 |   |
| 7. I could easily read the information presented on the IVIS display. | 4.21 | .72 |   |
| 8. The touch screen was easy to use to select IVIS menu options. | 3.38 | .97 |   |
| 9. The IVIS commander's display, approximately nine inch diagonal, is too small. | 2.21 | .83 |   |
| 10. The location of the IVIS "Own Location and Heading Window" is acceptable. | 4.04 | .86 |   |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

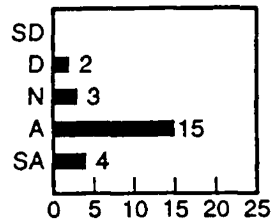
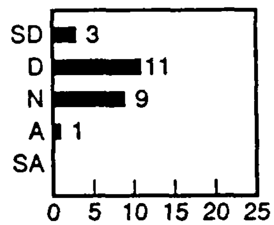
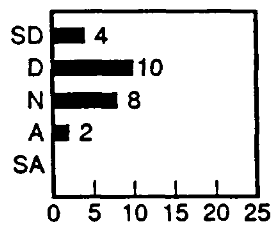
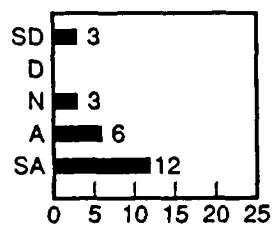
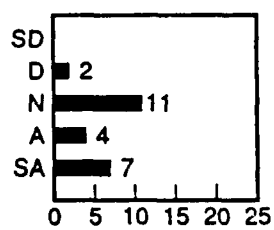
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 11. The location of the IVIS "Report Menu" is acceptable. | 3.88 | .80 |  |
| 12. The IVIS display functions were difficult to use while on the move. | 2.33 | .76 |  |
| 13. The IVIS display information was difficult to read while on the move. | 2.33 | .87 |  |
| 14. The IVIS map is more helpful for navigating than a paper map. | 4.00 | 1.35 |  |
| 15. I spent more time looking at the IVIS display than I did looking through the vision blocks and sights. | 3.67 | 1.04 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

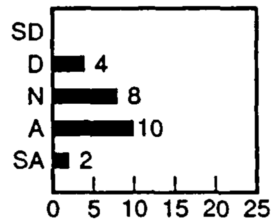
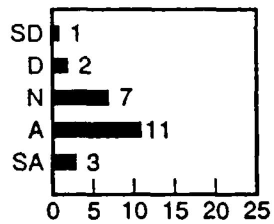
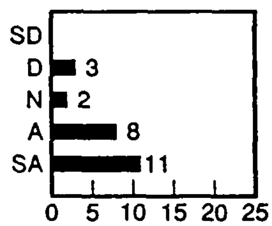
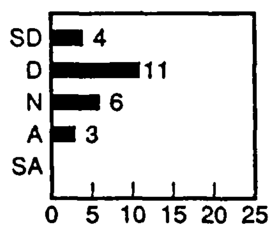
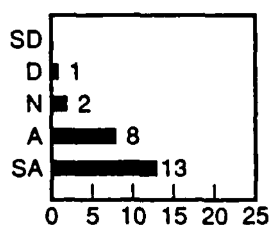
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 16. I spent more time looking at the IVIS display than I tactically should have. | 3.42 | .88 |  |
| 17. As I gained experience with IVIS, I spent more time using the vision blocks and sights and less time looking at the IVIS display. | 3.54 | .98 |  |
| 18. I gave the driver more control over the navigation of the tank than I would have without the IVIS display. | 4.13 | 1.04 |  |
| 19. I often used my paper map for navigating when I had IVIS. | 2.33 | .92 |  |
| 20. I spent less time communicating with the driver than I would have without the IVIS display. | 4.38 | .82 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

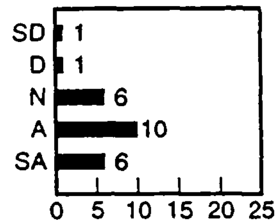
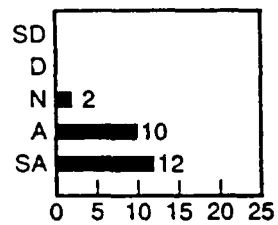
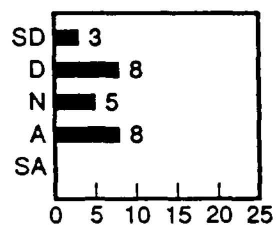
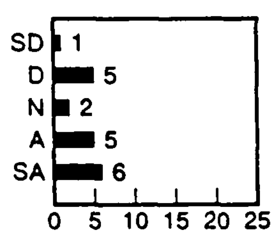
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 21. I rarely changed the terrain features which appeared on the IVIS map. | 3.79 | 1.02 |  |
| 22. The IVIS tank icon was useful for orienting my tank in the proper direction. | 4.42 | .65 |  |
| 23. I frequently changed the scale of the IVIS map. | 2.75 | 1.07 |  |
| 24. When navigating the current own-vehicle location update rate of every 10 meters is unacceptable. | 2.04 | 1.16 |  |
| 25. With IVIS, I had more time to acquire enemy targets. | 3.42 | 1.21 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

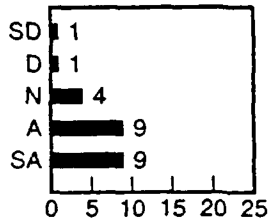
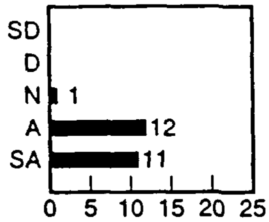
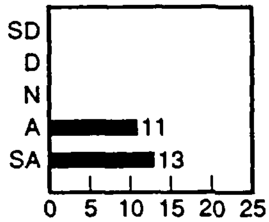
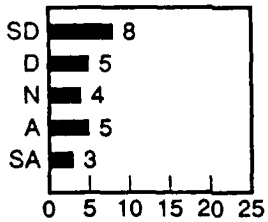
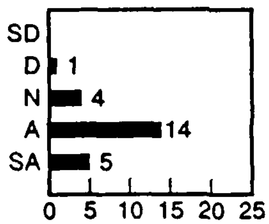
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 26. The IVIS system replaced the need for a compass for land navigation. | 4.00 | 1.06 |  |
| 27. I could easily enter waypoint grid coordinates for the IVIS "Route Designation" function. | 4.42 | .58 |  |
| 28. I could easily send waypoints to the IVIS driver's "Steer-to" display. | 4.54 | .51 |  |
| 29. IVIS waypoint updating should be under the driver's control. | 2.50 | 1.38 |  |
| 30. The IVIS tank icon was useful for orienting my main gun in the proper direction. | 3.96 | .75 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

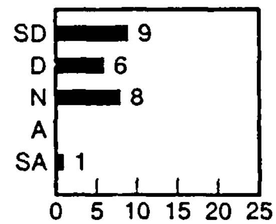
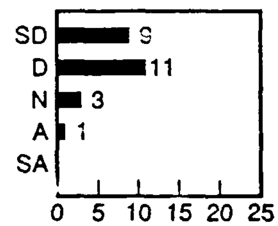
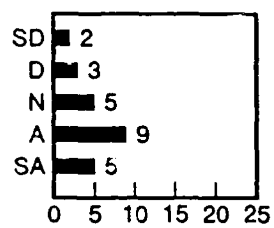
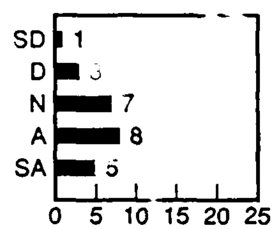
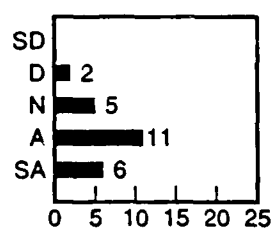
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 31. I had a difficult time changing IVIS "Route Designation" waypoint entries. | 2.08 | 1.06 |  |
| 32. I had a difficult time deleting IVIS "Route Designation" waypoint entries. | 1.83 | .82 |  |
| 33. I would rather see friendly tank icons on the IVIS map, as simulated in this test, than to see only their grid coordinates. | 3.50 | 1.22 |  |
| 34. When FRAGOs were sent using IVIS, I understood the commander's intent better than when FRAGOs were sent over voice radio. | 3.54 | 1.10 |  |
| 35. When using IVIS instead of the voice radio, I can react better to a battlefield intelligence report. | 3.88 | .90 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

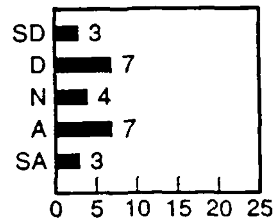
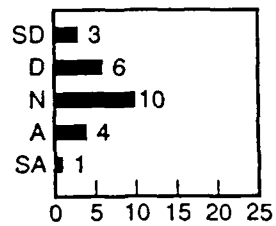
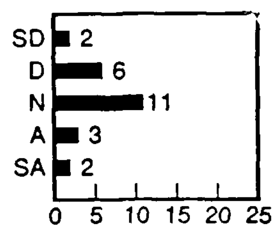
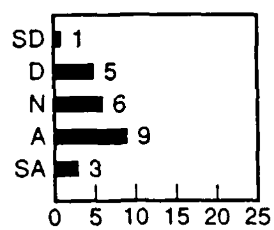
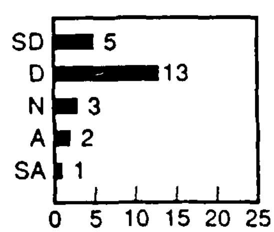
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 36. Visual alert signals (e.g., "MESSAGE RECEIVED"), without any auditory signals (beeps), would provide me with an adequate indication about reports and messages being received on my IVIS system. | 3.00 | 1.29 |  |
| 37. Auditory signals were a hindrance to my performance. | 2.75 | 1.03 |  |
| 38. Auditory signals distracted me. | 2.88 | 1.04 |  |
| 39. Auditory signals are needed to alert commanders of incoming IVIS reports, but the signals used in this evaluation should be improved. | 3.33 | 1.09 |  |
| 40. The way IVIS assigns priorities to reports and messages is difficult to understand. | 2.21 | 1.02 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

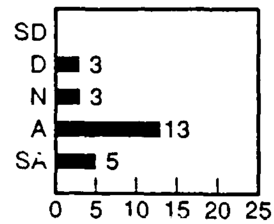
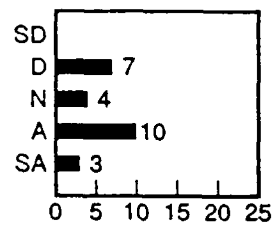
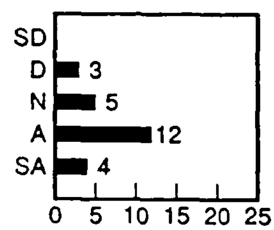
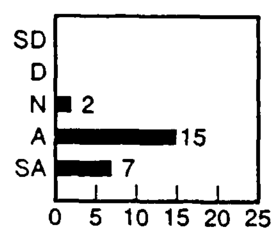
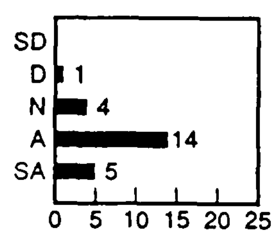
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 41. The way IVIS assigns priorities to reports and messages is acceptable. | 3.83 | .92 |  |
| 42. The touch screen capability of IVIS made it easy for me to prepare reports and messages. | 3.38 | 1.06 |  |
| 43. I sent more messages/reports over IVIS than I normally do using only the radio. | 3.71 | .91 |  |
| 44. I sent more accurate reports over IVIS than I normally do using only the radio. | 4.21 | .59 |  |
| 45. I gave more complete reports/messages on IVIS than I normally do using only the radio. | 3.96 | .75 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

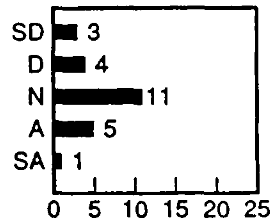
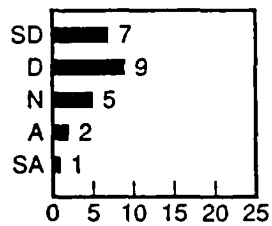
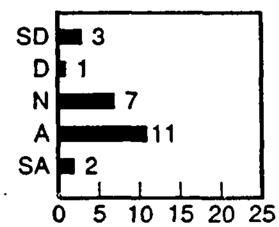
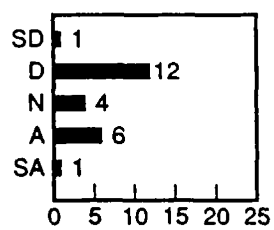
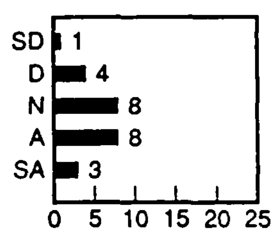
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 46. I spent more time sending messages on IVIS than tactically I should have. | 2.88 | 1.04 |  |
| 47. It takes longer to send messages on IVIS than on the radio. | 2.21 | 1.10 |  |
| 48. I liked the way IVIS offset the crosshair cursor so that my finger didn't cover the location I wanted to select. | 3.33 | 1.13 |  |
| 49. The IVIS touch screen was difficult to use. | 2.75 | 1.03 |  |
| 50. The "beeping" in the headphones to indicate an incoming message was a helpful feature. | 3.33 | 1.05 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

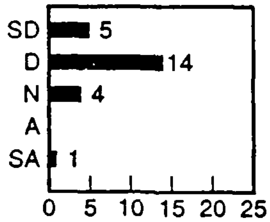
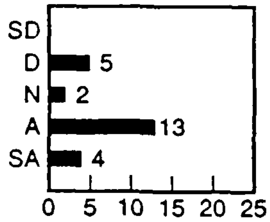
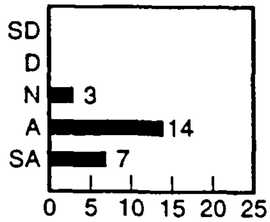
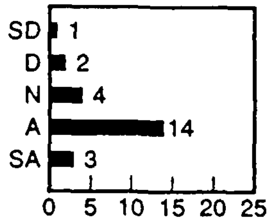
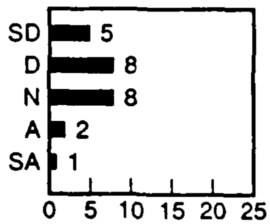
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 51. The navigation screen for selecting waypoints for a route was too sensitive. | 2.08 | .88 |  |
| 52. The "SPOT" report function on IVIS allowed me to enter all pertinent SPOT REPORT information. | 3.67 | .92 |  |
| 53. The ability to show various IVIS map features helped me navigate more effectively. | 4.17 | .64 |  |
| 54. The IVIS "SITREP" contained all pertinent SITUATION REPORT information. | 3.67 | .96 |  |
| 55. I still prefer to send reports over the radio rather than over IVIS. | 2.42 | 1.06 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

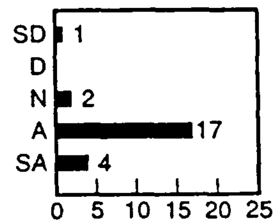
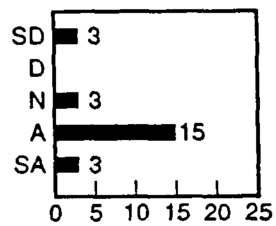
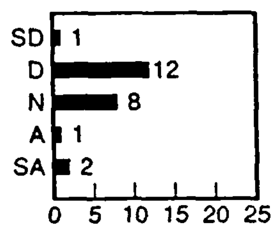
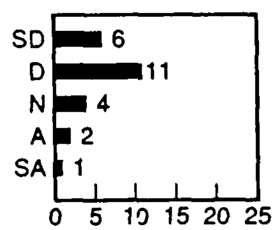
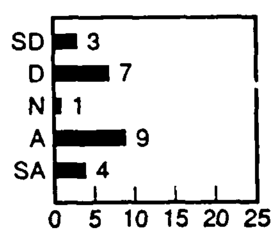
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 56. In adjusting fire, the meter increments of 500, 200, and 100 allowed me to pinpoint the target acceptably. | 3.96 | .81 |  |
| 57. Allowing the commander to adjust the cursor location on the map before removing his finger reduced input errors. | 3.63 | 1.14 |  |
| 58. I usually touched the map, rather than lased to the target, to enter grid coordinates into IVIS reports. | 2.63 | .97 |  |
| 59. I would prefer entering grid coordinates with a keypad, rather than touching the map, to enter route waypoints. | 2.21 | 1.06 |  |
| 60. I would prefer to also be able to enter grid coordinates with a keypad, in addition to touching the map, to enter route waypoints. | 3.17 | 1.37 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

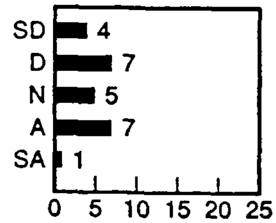
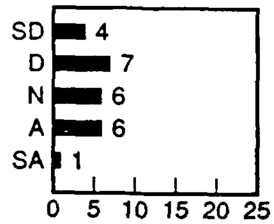
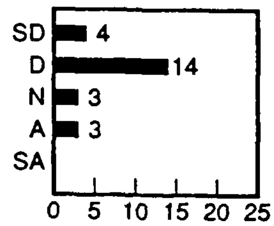
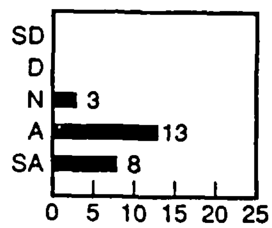
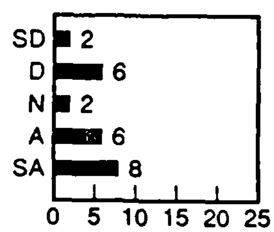
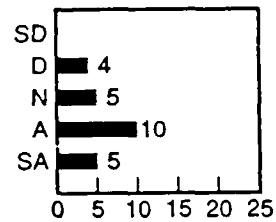
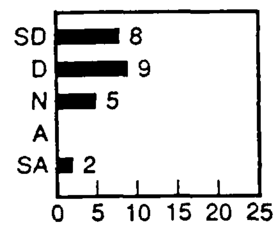
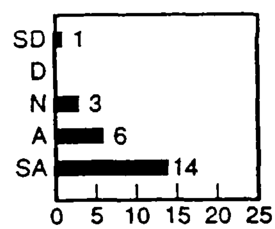
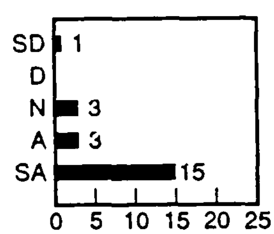
| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 61. I frequently added map symbols to my IVIS map display. | 2.75 | 1.19 |  |
| 62. I frequently added map labels to my IVIS map display. | 2.71 | 1.16 |  |
| 63. To keep the display simple, I usually removed the mission overlay from my operation overlay. | 2.21 | .88 |  |
| 64. The ability to give me the operational overlay on the IVIS map is an important IVIS function. | 4.21 | .66 |  |
| 65. With IVIS, I spent too much time reading reports sent by other TCs. | 3.50 | 1.41 |  |

Table I-1 (Continued)

IVIS Interface Questionnaire: Rating Means (M), Standard Deviations (SD), and Frequency Distribution

| Survey Question | M | SD | Response Distribution |
|---|---|---|---|
| 66. With IVIS, I need some kind of acknowledgment message that a report I sent is properly received. | 3.67 | 1.01 |  |
| 67. Overall, IVIS did not improve my performance. | 2.13 | 1.15 |  |
| 68. Overall, IVIS should be included in the upgraded tank. | 4.41 | 1.05 |  |
| 69. Overall, given the changes I request below, IVIS should be included in the upgraded M1A1 tank.<br><br>Requested IVIS changes are: | 4.41 | 1.05 |  |

# Appendix J

# IVIS Design Recommendations

Table J-1

IVIS Design Issues: Problems (P) and Potential Answers (A)

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Report Queueing and Routing

P: significant problems with queue length
A: generate report filtering routines to reduce number of duplicated or only slightly variant reports
A: aggregrate/consolidate report data by type, time, location
A: graphically present report data on IVIS map
A: multiple deletion options versus one-at-a-time
A: queue buffers/files needed for storage of messages other than the immediate queue
A: routing functions need major rework to eliminate "loops" and "boomerangs"
A: develop IVIS standard operating procedures, perhaps involving both radio and IVIS reporting procedures
A: allow commanders to customize routing routines prior to mission (based on unit operating procedures)

P: commanders can't get to latest report fast enough
A: stack reports in the queue by recency and priority (i.e., most recent, highest priority reports listed first)
A: present reports, particulary high priority reports, graphically on the IVIS map

P: commander's can't review/select messages based on time they were received
A: provide message received time data as part of queue library

P: if commander forgets to relay report or message before exiting to another function, the information is lost and the commander must request retransmission
A: system must store/file selected messages
A: before allowing commanders to EXIT a received message, might require, or better, remind user to SEND or RELAY

P: audio alerts distract some commanders and were ignored by others
P: the auditory priority beeps were ineffective
A: might use auditory signal only for highest priority reports
A: redefine priority assignment routines to reduce the number of reports identified as high priority (currently nearly all reports are high priority)
A: graphically show high priority reports on map display with initial auditory warning

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Table J-1 (Continued)

IVIS Design Issues: Problems (P) and Potential Answers (A)

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Report Queueing and Routing (Continued)

P: commanders repeat messages to ensure other commanders actually read report
A: incorporate message received acknowledgement message routine
A: generate IVIS standard operating procedures, perhaps involving both radio and IVIS reporting procedures

Report Receiving

P: commander can't always access available messages
A: dedicated **RECEIVE** key or greater availability of this key
A: save report menus, with information intact, while commanders leave function to receive incoming reports from queue (i.e., once report read, allow commander to finish current task)
A: add NEXT key on IVIS queue library to view additional pages

Graphics

P: symbol/label functions seldom used
A: need to rework functions to make much easier to use
A: must be able to send and store an entire overlay (rather than only create and send one symbol/label at-a-time
A: need both numeric and alphanumeric characters
A: need more rapid deletion procedures (rather than only being able to delete one symbol/label at a time)

P: graphics not scaled to map size (symbol/labels were too big and obstructed far too much of the map display)
A: graphics must be scaled

Vehicle Icons

P: commanders experienced difficulty distinguishing between icons
A: place bumper number or some other identifier on tank icons
A: scale icons to reduce icon overlap
A: redesign to ensure better icon differentiation

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Table J-1 (Continued)

IVIS Design Issues:  Problems (P) and Potential Answers (A)

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Scrolling

P: the scrolling crosswalk menu approach unworkable
A: need dedicated scroll function key, with supporting menu for scroll functions
A: redesign scroll drag and velocity functions to improve usability
A: allow commanders to change default own tank icon location

Touch Screen

P: calibration of cursor offset is difficult to maintain across vehicles
A: must stabilize calibration
A: provide commanders with calibration routine
A: explore other interaction capabilities

P: some commanders complained that their fingers were too big to allow them to accurately work with the touch screen
A: explore other interaction capabilities
A: redesign cursor to allow commanders to more rapidly see exact cursor location as they interact with IVIS

Shell Report

P: unrealistic format for SIMNET without dynamic terrain: can't specify number of craters or discriminate between mortar and artillery bombs
A: streamline shell report format to require only location entry)

Call For Fire

P: commanders occassionally direct artillery fire onto their own vehicle or other friendly vehicles (e.g., base CFF on inaccurate lase or fail to verify cursor location specificed after touching the map)
A: insert warning system in IVIS to notify commander that CFF grid is within XXX meters of own tank
A: insert objective system linked to tactical operations center to allow fire support officer to prevent fratricide given known friendly locations, and then automatically query commanders to redetermine enemy location

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Table J-1 (Continued)

IVIS Design Issues: Problems (P) and Potential Answers (A)

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Call For Fire (Continued)

P: commanders experienced difficulty using CFF adjustment request function
A: evaluate potential of numeric keypad to provide more precision in adjustments
A: an objective system linked to tactical operations center to allow fire support officer to project ultimate location of round impact
A: an object system within each commander's IVIS to allow him to see the estimated grid location for artillery impact (i.e., let the system do the work, not the commanders)
A: use default adjustment menu after suppressive fires

P: users concerned about whether sent reports are rapidly read and being acted upon (hence, duplicate requests often sent as a "reminder")
A: include acknowledgment routine to indicate status of CFF requests to commanders
A: generate IVIS standard operating procedures, perhaps involving both IVIS and radio reporting procedures

Position Navigation (POSNAV)

P: routes sent by other commanders automatically replace the receiving commanders' route selections
A: need capability to save more than one report
A: route files need to be labeled by source and time of transmission

P: DELETE key often wipes out entire list of waypoints when commander intended to delete only one or a few waypoints
A: need to be able to lock-in a set of waypoints
A: rework delete routine

P: commanders often confused by procedure for updating and monitoring status of driver's display
A: need an instructional prompt for forwarding waypoint to driver
A: need to clearly identify driver's display status

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Table J-1 (Continued)

IVIS Design Issues: Problems (P) and Potential Answers (A)

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Mils/Degrees

P: inconsistent usage and frequently not labeled
P: soldiers prefer degrees--have difficulty with mils
A: use degrees for all heading and orientation data, including the azimuth indicator and labels for the driver's display

Spot Reports

P: format difficult to use for indicating some common report information
A: add destroyed option on report format
A: generate IVIS report standard operating procedures, perhaps involving both radio and IVIS reporting procedures

Overall System

P: IVIS doesn't save files or status; when IVIS system crashes, and sometimes when the vehicles breakdown, all IVIS data is lost
A: IVIS must save its current and stored files

P: report format often extends across several pages
A: streamline report formats
A: rework data input routines to reduce number of pages

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